A TEA PLANT IN BLOOM.

U. S. DEPARTMENT OF AGRICULTURE.

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B. T. GALLOWAY, *Chief of Bureau.*

THE CULTIVATION AND MANUFACTURE OF TEA IN THE UNITED STATES.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., September 26, 1911.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 234 of the series of this Bureau a manuscript by Mr. George F. Mitchell, Scientific Assistant, entitled "The Cultivation and Manufacture of Tea in the United States," submitted by Dr. R. H. True, Physiologist in Charge of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

This bulletin brings together the most important results of the experiments in commercial tea culture begun by Dr. Charles U. Shepard, and later continued by him in connection with this Bureau. The work has been carried on at Summerville, S. C., and has been participated in on the part of the Department by Mr. J. H. Kinsler, Scientific Assistant, and later for a long period by Mr. Mitchell, the author of this bulletin. It is believed that this experiment has gone far to demonstrate the practicability of growing tea commercially in suitable parts of this country, and it should call attention to an important agricultural opportunity not yet accepted.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CULTIVATION AND MANUFACTURE OF TEA IN THE UNITED STATES.

HISTORY OF TEA GROWING IN AMERICA.

The tea plant seems to have been first successfully grown in this country by the French botanist Michaux, who planted tea about the year 1800 at Middleton Barony on the Ashley River, some 15 miles from Charleston, S. C. One of the supposed original plants, probably grown for their decorative value, survived and when seen by Dr. Charles U. Shepard about 25 years ago had reached a height of nearly 15 feet. The first attempt to introduce tea culture into America seems to have been made by Dr. Junius Smith, who in 1848 turned his attention to tea growing on his estate near Greenville, S. C., basing his effort on imported seeds and plants. In articles in the American Agriculturist of 1851 he stated that his plants had done well, having withstood a snowstorm of from 8 to 9 inches. He added: "I can not help thinking that we have now demonstrated the adaptation of the tea plant to the soil and climate of this country, and succeeded in the permanent establishment of tea within our own borders." Upon the death of Dr. Smith the tea plants left without care soon disappeared.

The interest of the National Government seems to have been first aroused in 1858, when, through the action of the Commissioner of Patents, Mr. Robert Fortune was sent to China to obtain seed for planting in this country. Plants were widely distributed in the Southern and Gulf States, and reports that they had been successfully cultivated were received from many persons. In a great many cases the growers made tea by domestic processes for home use, but no records of sales have been found. In 1880 the interest of the National Government in tea growing again revived under Commissioner of Agriculture William G. Le Duc, who, seeing that the introduction of the plant alone was not sufficient to lead to the development of an industry, secured the services of Mr. John Jackson, a tea planter of 14 years' experience in India, who was instructed to carry out the experiments necessary to test the feasibility of growing and

manufacturing tea in this country. An area of 200 acres of land near Summerville, S. C., was leased for 20 years from Mr. Henry A. Middleton, and tea seed was imported from Japan, China, and India, a small stock being also obtained from the few surviving plants previously distributed by the Patent Office. From the small tea fields resulting from these plantings, Mr. Jackson made small quantities of excellent teas which received the hearty commendation of prominent tea tasters to whom they were submitted. Before this work could develop materially Commissioner Le Duc was succeeded by Commissioner George B. Loring, who because of the illness of the tea expert, Mr. Jackson, and for other reasons caused the experiment to be abandoned.

About 1890 Dr. Shepard, believing that the experimental attempts previously made did not conclusively demonstrate that tea growing in the United States was out of the question, began the growing of tea, at first on a small scale. The reasons leading him to undertake seriously to do what had hitherto failed were several.

(1) The successful growth throughout the South Atlantic and Gulf States of a large number of oriental trees and shrubs demanding the same conditions as the tea plant seemed to indicate that the climate and soil were favorable.

(2) The abundance of suitable labor at a moderate cost furnished by colored women and children seemed to promise well, and the desirability of finding light labor during the summer season for these classes of the population seemed great.

(3) Thousands of acres of idle land, well suited to tea growing after proper preparation, could be made productive.

(4) Upwards of $16,000,000 sent abroad annually to purchase tea could be expended in paying for a home product.

(5) The American people could be supplied with a clean, pure article undeteriorated by a long ocean voyage.

Dr. Shepard believed that the previous attempts by the Government had failed partly because of administrative reasons, partly through the illness and death of the tea expert in charge and partly through a lack of persistence necessary to carry the work through to success. Pinehurst was selected as the location for his experiment because it was near the old experimental garden chosen by Mr. Jackson and because the somewhat rolling land contained a variety of soils. Furthermore, Summerville, being a popular winter resort for tourists, offered a special market for the product, and through the interest arising from the inspection of the tea gardens and factory and from "tea talks" given from time to time by the proprietor, this location seemed to present special opportunities for carrying on an educational campaign in favor of American tea.

DESCRIPTION OF THE TEA PLANT.

The tea plant, *Thea sinensis* L. (Pl. I), belongs to the family Theaceæ, a group especially well developed in tropical and subtropical regions and which includes the ornamental camellias. Although the home of the wild tea plant is not definitely established it appears that it is indigenous in Assam, where it occurs as a good-sized tree, reaching at times a height of 30 to 90 feet. It is supposed by Kiefer [1] to have been distributed from this general region to those parts of the world in which it is now known. For some time there was some doubt with regard to the number of species, but it seems to be generally accepted that the single species of Linnæus is alone valid, the supposed species of later botanists being no more than varieties. The difference in stature seen between the tea plant in cultivation and in these tropical jungles seems not to represent two botanical differences but to have arisen through adaptation and selection. In order to bring the plant within the range of commercial utilization its height is restricted by the method of growth and pruning to 2 to 6 feet.

The lanceolate to oblong-lanceolate, rather dully evergreen, serrate leaves vary in length from 1½ to 10 inches and in width from one-half to 4 inches. When mature they are rather thick, smooth and leathery, borne on a short petiole, and arranged alternately on the stem. The fragrant flowers, occurring singly or in groups of two or three in the axils of the leaves, consist of five conspicuous white petals which surround the showy group of many yellow stamens. The fruit consists of from one to three hard-shelled dark-brown nuts, somewhat resembling hazelnuts in size and shape.

In its ability to adapt itself to a wide range of conditions the tea plant is exceeded only by wheat, thriving from 30° north latitude in Japan to 31° south latitude in Natal, South Africa, and in Australia, and from 35° north latitude in the Western Hemisphere south into Brazil. Although this species as a whole has such a wide geographical range, not all varieties thrive equally well in any one locality. The Ceylon types from low altitudes do not thrive at high elevations on this island, nor will the broad-leaved Ceylon and Assam varieties flourish when transplanted to localities where the precipitation is small, where lower temperatures prevail, or where high winds are frequent. On the other hand, they do admirably where the rainfall is heavy and tropical temperatures prevail.

When the evaporation from the broad leaves tends to exceed the supply of moisture furnished by the roots, the plants either succumb or undergo a reduction of the leaf surface until they resemble the narrow-leaved stunted types.

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[1] Kiefer, A. Die Theeindustrie Indiens und Ceylons. Abhandlungen der K. K. Geographischen Gesellschaft in Wien, vol. 4, no. 3, 1902, pp. 1-66.

Other varietal differences appear in the chemical characteristics of the leaves, as is seen by the fact that certain varieties, such as the broader-leaved types represented by the Assam hybrid and Ceylon teas, are better adapted for making black tea, while the narrow-leaved Chinese and Japanese types are more suitable for the manufacture of green tea. These differences are due, as is more fully explained later, to the relative amounts of certain oxidizing ferments and oxidizable substances present in the leaves.

COMMERCE AND STATISTICS.

Tea is a staple crop of four countries, namely, India, Ceylon, China, and Japan, and at present extends the promise of playing an important rôle in the industries of the Southern States. The world's annual consumption, exclusive of the very large local use in China (the extent of which can not be determined), amounts to more than 700 million pounds, over 250 million pounds being produced in India, about 200 million in Ceylon, 150 million in China, 60 million in Japan, 20 million in Formosa, and 17 million in Java. Tea is raised also in Natal, in the Russian Caucasus, and to some extent in Jamaica. The people of the United States, although considered a coffee-drinking nation, consume annually upward of 100 million pounds of tea, for which $16,000,000 or more are paid.

Table I, presenting the imports of tea for every fifth year from 1853 to 1908, inclusive, shows a general increase in the quantity of tea imported, but the consumption per capita and the price per pound, although very variable, have on the whole decreased.

TABLE I.—*Imports of tea into the United States every fifth year from 1853 to 1908, inclusive.*

Years.	Quantity imported.	Import value.	Average import price per pound.	Consumption per capita.
	Pounds.		*Cents.*	*Pounds.*
1853	22,721,745	$8,224,853	36.4	0.75
1858	32,995,021	7,261,815	20.4	.97
1863	29,761,037	8,013,772	25.8	.80
1868	37,843,612	11,111,560	29.2	.96
1873	64,815,136	24,466,170	37.7	1.53
1878	65,366,704	15,660,168	23.6	1.33
1883	73,479,164	17,302,849	23.5	1.30
1888	84,627,870	13,360,685	15.8	1.40
1893	89,061,287	13,857,482	16.0	1.33
1898	71,957,715	10,054,283	13.9	.94
1903	108,574,905	15,659,229	14.4	1.30
1908	94,149,564	16,309,870	17.3	1.07

Of the 94,149,564 pounds imported in 1908, about 27 million came from China and 47 million from Japan, the other 20 million coming from India and Ceylon. Although the two latter countries have made every effort to gain prestige in the tea trade and are gaining every day, the Chinese and Japanese teas are still in the lead, owing perhaps to the demand for green and oolong teas. This demand so far

has not been successfully met by Ceylon and India, but black teas are constantly becoming more popular in the United States and in time may supplant the green teas, as has been the case in Great Britain.

It is possible that by establishing a tea industry at home the consumption of tea in the United States can be greatly increased, as it has been in Great Britain since tea became a staple crop of her colonies in the East Indies.

ESTABLISHING A TEA PLANTATION.

Selection of sites.—The land for a tea plantation should be comparatively flat and uniform over large areas in order to admit of the use of farm machinery and to save the time lost in moving from one small field to another when cultivating and gathering the crop. Cleared land should be selected in order to avoid the expense of removing forest and undergrowth, which at the present price of labor would be very great. The site should be convenient to railroad or river transportation, but away from mining, manufacturing, or truck-growing centers, where labor usually commands a price too high to pay for ordinary farm help. As all the members of a family may be employed in the work of a tea plantation there should be many separate houses provided for laborers in order to guarantee an abundance of labor at all times. A sufficient and convenient supply of fuel for future factory requirements must also be provided.

Other things being equal, it is better to avoid hillsides for tea gardens, since they are difficult to cultivate and are subject to denudation by heavy rains. The familiar representations of Chinese tea gardens as seen on our grandmothers' blue china relate rather to the cultivation, largely by priests, of very high-grade tea on precipitous mountain slopes where the declivity is so great that in some instances it is necessary to use chains in order to prevent the laborers from falling into the intervening valleys. Again, in the tea gardens on the mountain slopes of the Himalayas and the more elevated districts of Ceylon the tea has to be planted on terraces which are costly to construct and which can not be cultivated with other than manual tools, thus increasing the expense of production. Moreover, such situations are liable to disastrous landslides.

Climate.—The climate of the Southern and Gulf States is in general fairly suited to the cultivation of the tea plant. Although the rainfall is much less than in most of the tea-producing countries, the average annual temperature is lower; hence, less evaporation and therefore less rainfall is needed.

The tea plants, except those from tropical climates, can be safely cultivated where the temperature seldom falls below 20° F. (beyond that degree of cold lies considerable danger), and where the annual

precipitation amounts to 50 inches or more. At least 30 inches should fall during the cropping season. For a successful yield the mean temperature for the plucking season should not fall below 70° F. If there is plenty of rain, high temperatures increase the rapidity of growth. Frequent winds, especially if dry and hot, are very detrimental to tea culture, as also are long periods of drought. Cool nights in summer interfere with rapid and luxuriant growth and materially reduce the yield. The rainfall should be evenly distributed during the plucking season, downpours doing relatively little good to the plants and generally proving very destructive in consequence of the denudation of the soil.

An endeavor has been made to supplement the rather scanty rainfall at Pinehurst during the cropping season by a system of irrigation, both superficial and at a shallow depth from the surface, so as to offset the generally larger water supply of the Oriental tea gardens; but the result thus far has not proved successful. The failure probably arises from the inadequate supply of water at the critical periods of drought. If the tea gardens were placed on some of the abandoned rice fields of the South Atlantic coast the old sources of artificial irrigation might be advantageously utilized to remedy any deficiency in this respect.

Soil.—For its successful growth the tea plant requires a deep, fertile, well-drained, friable, and easily penetrable loam containing a large amount of well-decomposed organic matter. The soil should be thoroughly drained, naturally or artificially, to a depth of at least 36 inches. Very tenacious undrained soils or very sandy soils that lack water-retaining properties are not adapted to the growth of tea; neither will the plant tolerate stagnant water in the subsoil. The best tea soils contain very little lime, and when this constituent exists in excess it seems to be deleterious to the growth of the plant. Although the soil must be well supplied with thoroughly decomposed organic matter, an excessive quantity causes the leaves to develop rapidly and the tea produced from them is very weak. The quality of the tea depends largely on a sufficient supply of phosphoric acid and potash.

Seed.—In establishing a tea plantation there is nothing more important than the selection of seed, especially when it must be imported. The average cost of imported tea seed exceeds $50 per 100 pounds delivered in the Southern States, and when it is considered that about only one in three shipments arrives in good germinating condition the cost of importation assumes a high figure. The seed should be packed in dry earth or charcoal, or both, in metallic or strong wooden boxes and hermetically sealed. A box of 100 pounds of tea seed contains from 30,000 to 40,000 seeds and the

germination will vary from 95 per cent to zero, according to the success of the importation.

In this country the seed is ready to be gathered in October and November. With some varieties and in some localities the seed matures earlier than in others. Seed that has dropped on the ground should be avoided as inferior. It is better to select the capsules containing the seed from strong healthy plants and spread them out in some dry building to open. As soon as possible every tea planter should establish a seed grove where the plants are rarely, if ever, pruned. Bushes can not be expected to produce both leaf and seed in quantity and quality. Hence, a garden cultivated for leaf should produce a minimum amount of seed. The best quality ("jat") generally yields the least seed. If more than one variety is planted on an estate the seed groves for the respective sorts should be well isolated in order to prevent hybridization.

Tea seed gathered from the gardens at Pinehurst costs less than $5 per 100 pounds. The expense of importation will be unnecessary as soon as tea gardens become general in this country, and those that have done best locally are now produced on the Pinehurst estate. It has been found that plants once removed from the original imported seed do as well as those grown from imported stock.

Although at Pinehurst success has usually followed the attempts to raise seed from most of the tea-producing countries, the following may be especially recommended as profitable: The "Darjeeling" from the Himalayan slopes of British East India, probably a cross between the Chinese and Assamese varieties, is well adapted for the production of both green and black tea, as are also the Ceylon varieties from very high altitudes (not less than 5,500 feet). The Chinese variety is especially adapted to the making of green tea, but gives a comparatively small yield. Excellent results have been obtained from a hybrid of the Assamese and Chinese types, locally called "Assam hybrid," but this variety does not make green tea of as fine quality as those before mentioned.

In pruning tea plants most of the embryonic seeds are removed, but with careless pruning many are apt to be left on the bushes, with the result that a large amount of the food supply of the plant is used up in maturing the seeds, as is shown by the following experiment: The field selected was pruned less severely than usual, but apparently no great excess of young seed had been left on the bushes. The plants were about 8 years old, of the Assam hybrid variety, planted on comparatively rich loam 5 feet apart, and capable of yielding about 250 pounds of dry tea to the acre. The seed was gathered in October, at which time the plants were about 4 feet tall. The previous spring each plant had received one-sixth of a pound of

a complete commercial fertilizer; that is, 300 pounds to the 1,750 plants on 1 acre. Each bush averaged 1 full pound of partially dried seed. An analysis of this seed was made by the Shepard laboratory of Charleston, S. C., with the results shown in Table II.

TABLE II.—*Analysis of tea seed left to mature after insufficient pruning of the plants, giving amount of loss of fertilizing material.*

Determinations.	With moisture present.	On a dry basis.	Loss per bush bearing 1 pound of seed.	Loss per acre on 1,750 plants.	Pounds per acre in chemical manures applied the previous spring.
	Per cent.	*Per cent.*	*Grains.*	*Pounds.*	*Pounds.*
Moisture	9.55	....	....	....	....
Nitrogen	1.70	1.84	129	32¼	....
Equivalent of NH_3	2.06	2.27	159	39¾	12
Phosphorus	.32	.35	24½	6⅛	12
Potash	.85	.94	66	16½	12

From this analysis it will be seen that a very considerable amount of plant food is likely to be appropriated by the seed if it is allowed to mature, because the plants are not pruned. In this experiment the pecuniary value was more than double the cost of the commercial fertilizer applied.

Nurseries.—The native seed should be planted in the autumn or early winter following the gathering; imported seed should be planted as soon as it arrives. A plat of particularly fertile, well-drained, loamy land convenient to the proposed garden should be selected. Where droughts may be anticipated, it is well to locate the nurseries near a sufficient water supply. The soil should be well tilled to a considerable depth, and all roots, stones, and other obstacles removed. The beds should be made 5 to 6 feet wide with passages left between them from 1 to 2 feet in width and 8 inches deep. These passages may serve as drains. The beds should be carefully raked over and leveled.

The seed should be placed 4 by 4 inches apart and 1½ inches deep in little holes made with a round, pointed stick about an inch in diameter. The depth can be regulated by placing a crosspiece 1½ inches from the pointed end. One seed should be placed in each hole and covered by simply leveling the surface. The nursery bed should be uniformly covered with some kind of straw to protect the seeds from cold and also to serve as a mulch. Pine straw (needles) has been found excellent for this purpose. As soon as the seeds begin to sprout a light frame should be set up in the passages 6 feet above the ground, supported by posts (fig. 1). The overhead frame should have spaces 1½ inches wide so as to admit a portion of the direct rays of the sun. It can be made from any waste lumber or loosely woven wire netting and should be covered thinly with straw of some kind.

When the plants begin to come up, some of the straw should be removed from time to time and the nursery thoroughly weeded. This should be kept up until autumn, when the straw may be entirely removed and the top of the frame dispensed with. When ready to transplant, preferably after one to two years' growth in the nursery, the seedlings are removed by loosening the soil with a spade and lifting them out with only such earth as clings to the rootlets. The roots must be carefully protected from wind and cold and also from the hot sun until duly transplanted. When very young plants are to be removed, say, six months after germination, it is better to remove them with a ball of earth, which can best be done by the use of a suitable transplanter. If the plants are left in the nursery longer than one year they should be pruned back. This causes them to branch out instead of developing into mere switches.

FIG. 1.—A tea nursery.

Planting.—Too much care can not be exercised in the preparation of the land for tea. It should be entirely cleared of trees, stumps, roots, and grass and thoroughly drained when necessary by a system of underdrains or ditches at least 3 feet deep. Virgin land always does best when planted to some crop that requires constant cultivation the summer before setting out the tea seedlings. Indeed, previous to setting out the seedlings it is well to grow a crop of cowpeas or some other leguminous plant, which should be turned under by breaking the land flush with a three-horse plow. After the legumes decay in the soil the land should be thoroughly disked and harrowed.

In the case of hillsides it is best to construct terraces. Transplanting in this climate should be done in the late autumn.

There are two systems of planting that have given good results at Pinehurst, namely, in checks and hedges, each having its advantages under the respective conditions. When planted in checks, either rectangular or in the form of a quincunx, the latter method is to be preferred, as it affords more "plowways," thus allowing the fields to be kept clean with much less hand labor. The plants should be set out from 4 to 5 feet apart each way, which arrangement will accommodate about 2,700 and 1,750 plants to the acre, respectively, the distance varying with the habit of the variety used and with the fertility of the land. On hillsides as an aid to the prevention of washing out and on very rich lands able to stand a luxuriant growth, planting in hedges is preferable, and the plants should be placed 18 inches apart in 5-foot rows. When planted on hillsides the rows should follow the contour of the slopes, thus assisting in carrying off any excessive rainfall at a less grade and inflicting less damage than if it were permitted to descend the slopes directly. Hedges require more careful hoeing at first, but later are easier to prune and to pluck. The greater number of bushes to a given area used in hedge planting generally produces a larger quantity of tea.

Regularity must be insisted upon in planting, as it not only presents a better appearance but renders the cultivation easier. Definite lines should be laid out with the plow and checked at the proper distances. Where the furrows intersect, holes should be dug 10 inches square and at least a foot deep. If the plants are tall and slender or have much foliage it is better to prune them, leaving only a few leaves. This is best done with large hand shears before removing the plants from the nursery. The object of this pruning is to reduce the amount of evaporation from the plant proportionately to the disturbance of the roots caused by transplanting. The plants should be placed in the middle of the holes with the taproot straight down, and if the taproot is too long it may be cut off with a sharp knife on a slant. The seedling should be planted at the same depth it grew in the nursery, because if too high some of the slender roots will be exposed and if too low the bark above the surface will enter the soil, which is detrimental to the growth of the plant. About half the earth should be put back in the hole and thoroughly packed, which is best done by treading with the feet; then a quarter more should be added and this thoroughly packed. The remainder should be filled in but left loose in order to mulch the plants.

Cultivation.—Frequent and shallow cultivation that will maintain a loose mulch around the plants as well as keep them free from weeds is especially important during the spring and early summer, when

evaporation is very pronounced and the usual rainfall scant. Shallow mulching is best attained by single-horse sweeps, which can be run very near the plant. Young fields planted in hedges require weeding and hoeing about the stems two or three times during the season. Where the tea is planted in checks this is rarely necessary, as it is possible to keep the plants fairly clean by plows and cultivators. Hoeing is especially necessary when the grass starts in the rainy season. In the autumn after the plucking season is over, the soil should be turned up thoroughly to a considerable depth with single-horse turnplows so that aeration and disintegration of the soil may take place during the winter when there is very little evaporation.

When cultivating, care must be taken that the young plants are not injured by the hoes or covered up by the plows and cultivators. The young gardens require more attention than the older ones, as the bushes of the latter shade the ground and keep down weeds and grass and prevent evaporation from the soil.

A careful comparison of the labor required in the field and factory work of a given tea area in the Orient and at Pinehurst shows that in the Orient at least twice as many laborers are required as at Pinehurst, where mechanical devices in the field and factory are used. It is granted that wages are much higher in this country, even among the southern negroes, although of late years wages have materially advanced in parts of the Orient. Thus a difference in the cost of labor, which would appear to condemn the attempt to establish a tea industry here, does not exist to the extent usually believed. However, economy makes it necessary to substitute for hand labor improved and often special forms of agricultural implements.

Manures.—For the first few years after a plantation is started, manures are unnecessary in ordinarily fertile soil. When to begin the use of fertilizers and how much to apply depend entirely on the richness of the land. On very rich, easily penetrable soils the root system extends over such a large area that it is perhaps never necessary. At Pinehurst the lands are generally poor, and it has been necessary to manure most of them, but in some of the richest gardens this has not been required thus far. The richest lands in this section are low and have always been wet and consequently sour. Tea will not tolerate subsoil water or sour lands. Hence, after proper drainage, it is often desirable to apply caustic lime or, better, burnt marl, especially that containing phosphate of lime, not only as a corrective of acidity but also for its decomposing effect on the organic matter in the soil and the liberation of valuable mineral plant food otherwise unavailable. One-half ton of burnt marl, or perhaps 500 pounds of caustic lime, to the acre is sufficient under ordinary circumstances at Pinehurst.

The color of a healthy tea garden in the spring or early summer is a bright, yellowish green. Often before plucking it is decidedly golden, from the general development of pekoe tips. At the close of the cropping season and in the winter it should assume a lustrous, dark-green color. The color of the "shelter" tea (that protected from the direct sunlight during the summer) is of a decided blue tint. Whenever the leaves turn yellow, it is at once necessary to discover and remedy the cause, which is usually lack of nourishment or the presence of stagnant water about the roots.

Thus far no depredating insect, worm, or mildew has to any appreciable extent invaded the Pinehurst tea gardens. Considering how seriously they have injured the oriental estates, this is remarkable. The army worm has at times removed the grass from about the tea bushes, but has not attacked them. The mealy bug has made an occasional appearance, but has been readily extirpated by pruning and burning the attacked foliage. The red spider has given some trouble on tea plants elsewhere in the State, but not at Pinehurst. This insect yields to spraying.

A falling off in production, when it can not be attributed to one of the causes mentioned, generally indicates that enrichment of the soil in some form is needed. There is nothing better for the plant than heavy applications of barnyard manure in the furrows between the plant rows, especially if fortified with available phosphoric acid and potash. At Pinehurst most of the fields have rather poor, thin, sandy soil and are therefore deficient in all of the essential principles of plant food; consequently, most of them have had to be enriched. This has generally been effected with a fertilizer containing 4 per cent each of available (mostly soluble) phosphoric acid, potash, and ammonia, the last from dried fish scrap and dried blood. The manure should not be placed so near the plant that the minute feeding roots which take up the plant food may suffer injury from the plowing. The manures are best applied late in the winter or early in the spring and plowed under with the tea prunings. Cowpeas or some other suitable legume should be planted between the rows in the summer and plowed under late in the fall. Their function is threefold, namely, to shade the soil from the hot sun, to loosen up the earth by means of their roots, and to enrich the soil by the addition of their substance.

Pruning.—The tea plant is naturally arborescent and when uncultivated simply clothes itself with sufficient leaves to maintain its growth. This growth would be insufficient for a profitable tea estate and the bushes would attain too great a height for plucking. For these reasons the tea planter prunes his bushes, depriving them of a portion of their stems and leaves. This disturbs the natural equilibrium between root, stem, and foliage, with the result that nature

is spurred to restore the usual proportion by the luxuriant production of young leaf. It is not until the planter ceases his inroads on the gardens that the equilibrium is restored.

There are a great many systems of pruning used in India, Ceylon, and the other tea-producing countries, each claiming special advantages, but they may be simply adaptations to local conditions. The system practiced at Pinehurst is as follows: The first year after being transplanted into the field the plants are lightly "nipped" with the shears to induce them to put out lateral branches. The second year the bushes are pruned about 15 inches above the ground. Each succeeding year's pruning is about 2 inches above that of the previous year until the yield begins to diminish or until the plants become too tall for picking, when they should be heavily pruned about 14 inches above the ground. This should not be necessary until after the fifth year. Later on, if the bushes continue to fall off in their yield after being properly cultivated, manured, and plucked, they should be "collar pruned," that is, pruned to the ground. This causes them to put out an abundance of new shoots, which can be picked late in the same season. In all cases the prunings should be buried in the middle of the rows.

Pruning is not only a long and tedious operation but is attended with great expense, costing from $2 to $3 an acre. By the use of the mechanical pruner, constructed by the writer at Pinehurst, this cost is materially lowered. With this reduction in the cost of pruning, the bushes may be lightly trimmed in the early summer after the second plucking, as is done in Japan. It is hoped that this will increase the yield here as it does there, and it is the writer's opinion that with the systematic use of the mechanical pruner the tea bushes will become so regular in their growth that its use as a mechanical plucker also may become feasible.

By burying the tea prunings a quantity of plant food is returned to the soil, to say nothing of the improvement exerted by their physical effect on the land. The composition of such prunings, as determined by an analysis made in the Bureau of Chemistry, is given in Table III.

TABLE III.—*Analysis of tea prunings.*

[Made on a dry basis.]

Determinations.	Leaves.	Twigs.
	Per cent.	*Per cent.*
Nitrogen	2.77	0.95
Potash (K_2O)	1.44	.71
Phosphoric acid	.50	.25

As the result of an experiment instituted on rather luxuriant bushes, Dr. Shepard calculated that the prunings per acre contained

95 pounds of combined nitrogen, 56 pounds of potash, and 19.6 pounds of phosphoric acid. The necessity of restoring this material to the garden by plowing it in becomes evident when it is considered that its value, judged at the present cost of commercial fertilizers, is equivalent to three times that of the 600-pound application of a comparatively high-grade and complete fertilizer which was applied in the previous spring at a cost of about $7.50 per acre.

Before being covered in the trenches, the prunings between the tea rows should receive a dressing of acid phosphate and kainit or of burnt marl to hasten their decomposition. That they prove of great assistance to the plant is obvious from the large number of rootlets which within a year permeate the remains of the prunings.

At the beginning of the experiments it was thought desirable to limit the tea bushes to one stem. The pruning, therefore, conformed to that principle, and the centers of the plants were cut out, so as to admit of the free circulation of air. An unusual degree of cold, however, very shortly demonstrated that the single stem, unprotected by foliage, left the bark too much exposed to the weather, causing it to split and necessitating the cutting back of the plants to the ground. By promoting the growth of many shoots from each root the tea plant is fully protected by the enveloping foliage from all but very cold storms. When they occur, especially before the bushes have entered upon their dormant period, collar pruning becomes necessary.

It is particularly desirable to maintain a few young and straight stems as the source of the expected crop and to cut out as far as the cost of the operation will allow the "crowfeet" and other tangled masses of generally old and less valuable branches.

The whole operation of pruning implies constant supervision. As formerly practiced at Pinehurst with several sorts of shears and occasionally with saws, it is laborious and requires some knowledge and attention on the part of the pruners. The important question of when to cut low should be determined by the quality of the previously recorded crops, as well as by the condition of the garden at the time of pruning.

Plucking.—In plucking, which begins at Pinehurst about May 1 and continues into October, only the bud (pekoe tip) and the first two leaves are taken (fig. 2), the other leaves being generally too tough in structure and deficient in the valuable principles to make superior tea, although in the Orient the third, fourth, and fifth leaves are generally plucked. Plucking should be done by pinching off the stem with the thumb-nail and first finger just under the last leaf to be picked. The tea planter has to decide whether he will pluck for quality or quantity, and this must depend largely on his market.

COLORED CHILDREN PLUCKING TEA AT "PINEHURST," SUMMERVILLE, S. C.

The number of "flushes" and pluckings is influenced very largely by the methods employed. When plucking practically strips the shoots of stems and leaves, little opportunity is given for the formation of subsequent shoots. Therefore, in parts of the Orient the heavy cropping during the early summer is apt to leave the plant stripped of its tender stems and hence of the dormant buds. In those countries the number of pluckings rarely exceeds 3, whereas in India and Ceylon it frequently exceeds 20.

At Pinehurst the bushes are plucked every 7 to 15 days. The interval is determined by the development of the tender foliage, care being taken that it does not become tough before being plucked. If the leaves are plucked when too young, there is a decided loss in the tea produced; therefore, much judgment must be exercised in determining the proper time. The plucking of the pekoe bud and the first two leaves forces out the buds at the bases of the axils of the remaining leaves, and shoots, with the usual complement of leaves, develop in about three weeks. After the leaves of these shoots are plucked a third growth arises from the buds at the axils of the unplucked leaves, and, when these are taken, a fourth, and possibly a fifth, series follows in like manner. These growth periods are known as "flushes."

FIG. 2.—A tea shoot, showing the part to be plucked.

Although there are probably not more than 5 flushes, there may be 20 or more pickings, due to the fact that all the shoots in a flush do not develop at the same time; hence, pluckings are necessary at frequent intervals to keep pace with the continued development. At Pinehurst the plucking is done by colored children (Pl. II), who with proper supervision soon become expert in their task and, if available statistics are correct, equal and sometimes surpass the tea pickers of the Orient in the quality and quantity of leaf plucked. Under favorable conditions the children average each day about 40 pounds of green leaf, which equals 10 pounds of dry tea, but some have plucked as much as 75 pounds, which is equivalent to 18¾ pounds of dry tea. At present the Pinehurst gardens yield annually up to 600 pounds of finished tea per acre, depending on the variety and age of the plants, fertility of the soil, rainfall, temperature, and fineness of plucking.

If to a plucking of the pekoe tip and the two leaves immediately below, the third leaf (first souchong) be added, the weight of the crop is almost doubled, and if to the pekoe tip and three leaves the fourth leaf (second souchong) be added, the output is again almost doubled. It is highly probable that wherever tea is cultivated all the leaf comprising the different commercial grades is taken at one time by the pickers. Its separation into the trade grades that receive varying valuations is effected by screening at the close of the curing, since by common consent the finer the leaf, after the dust has been removed, the better the product. Leaves slow in developing make a better flavored product than those that grow rapidly, so that a small yield is generally compensated for by a more highly flavored tea. The cost of plucking averages about 1 cent for each pound of green leaf, making about 4 cents a pound for the dry tea. This perhaps can be materially reduced in many localities where the negro population is greater. The plucked leaves should not remain in the gardens, but should be taken to the factory at frequent intervals during the day. Constant and thorough superintendence is absolutely necessary if success in plucking is to be assured.

CURING, OR MANUFACTURE.

Since the distinction between the green and the black teas has already been briefly indicated and reasons assigned for the manufacture of the one or the other type, or both, in any given locality, a brief description of the processes for curing the different sorts may be entered upon.

BLACK TEA.

In curing black tea there are four important steps: Withering, rolling, oxidizing, and firing.

The functions of these operations may be summarized as follows:

Withering is a preparatory step to rolling, resulting in a desired loss of water and a flaccid mechanical condition of the leaf.

Rolling determines the strength of a tea and prevents in a measure its deterioration.

Oxidizing imparts to black tea its color and flavor.

Firing develops the aromatic principle in tea.

Withering.—When the "leaf" is brought into the factory, it is carefully weighed and inspected to see that the leaves are tender and fit for making tea (fig. 3). If any tough leaves or large stems are found, they must be culled out by the picker who brings them in. The leaves are then carried to the lofts, where they are spread very thinly and evenly on the withering trays and floors. It requires about 1 square yard of space for withering each pound of fresh leaf. To spread the leaves properly they are tossed up, giving the wrist an

abrupt turn as they leave the hand, which causes them to fall evenly. From 12 to 24 hours are required for withering, the time depending largely on the temperature and humidity. During the process the leaves lose about half their weight by evaporation, turn darker by partial oxidation, become soft and flaccid, and emit an agreeable and characteristic odor.

Rolling.—When withered they are ready for rolling, the process at Pinehurst being carried on entirely by machinery. In most tea countries the rolling by hand and foot has been displaced by the use

FIG. 3.—Weighing and inspecting the leaf.

of machinery, chiefly because it is cheaper, cleanlier, and more uniform in the result. At Pinehurst single rolling machines are doing the work which would otherwise require the labor of a hundred men or more (fig. 4). During the operation of rolling the cells of the leaves are broken and the juices which contain the principles necessary to good tea are spread over the surface of the rolled leaf, where they are subsequently dried on, easily accessible to the hot water used in making the infusion. The rolling reduces the exposed surface of the leaf, imparting to it the familiar twist of most commercial teas and thus assisting to preserve the aroma.

Rolling requires from 40 to 60 minutes, the last half of the time under increased pressure. After this process the "roll," as the mass of wet leaf is called, is put through the "ball breaker" (fig. 5). This apparatus consists of a revolving horizontal cylinder, covered with

wire cloth of quarter-inch mesh and equipped with arms revolving in opposite directions. These arms break up the lumps of moist matted leaf and separate the fine and well-rolled leaf from that which is coarse and incompletely rolled. The latter is rerolled under heavy pressure.

Oxidizing.—The rolled leaf is then carried to the oxidizing room and spread in a layer about 2 inches thick on clean wooden tables (fig. 6), and clean cloths moistened with water are supported over them on wire frames. The oxidizing room should be kept clean,

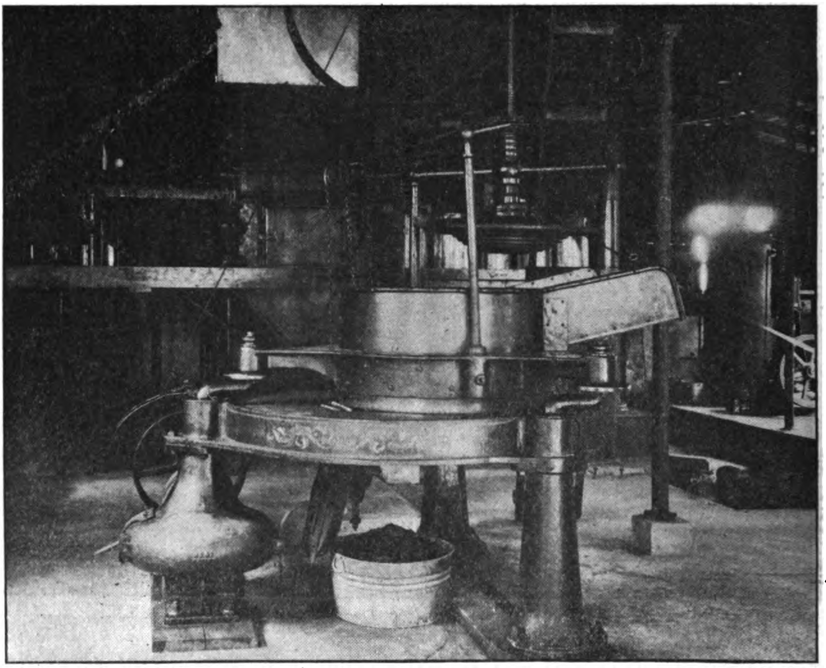


FIG. 4.—A tea-rolling machine.

damp, and as cool as possible. The best results are obtained where the temperature is regulated at 75° to 84° F. Under these conditions the leaf gradually changes from a dark-greenish to a coppery color and the leafy odor is converted into a characteristic fruity one. If the oxidation be too long protracted, the leaf assumes a dull copper-red color, and while the manufactured tea would give a deeper colored liquor it would be weak and lacking in aroma. Oxidation requires from two to six hours, the proper time to stop the operation being determined only by experience. The transformation should be by oxidation and not by fermentation, which produces acidity, the slightest trace of which is ruinous to tea.

Firing.—After the leaf is oxidized it is dried or, as it is called, "fired," which process has for its object the dissipation of the moisture from the leaf and the development of the characteristic aroma or fragrance of tea. The rolled and, in the case of black tea, the oxidized leaf contains much water, chiefly the natural juice of the leaf, but frequently in part the result of sprinkling during the preceding operations. Whatever the source of the moisture it is necessary to forestall any fermentation likely to arise from it by firing as soon as the leaf is ready for that process. This is now accomplished in most countries which produce commercial teas by the use of drying machines. This machine (fig. 7) may be briefly described as an inclosed

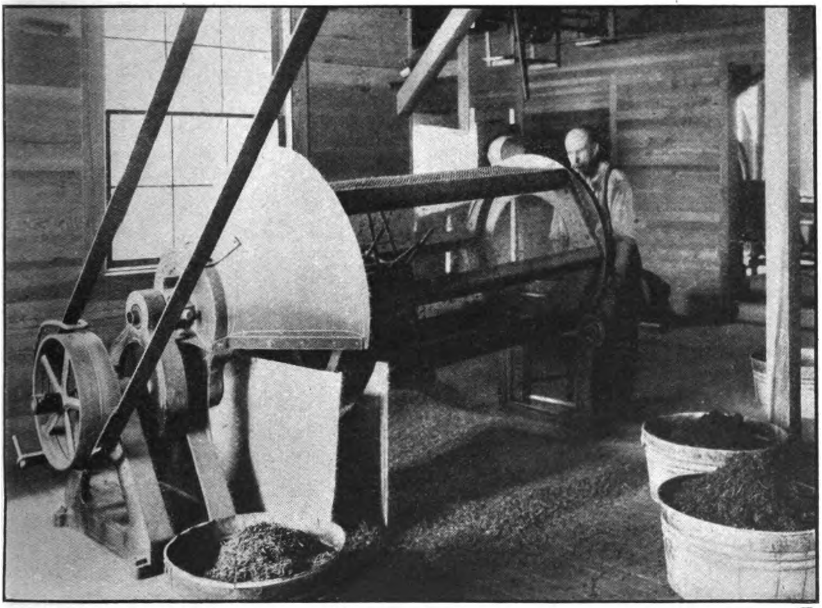


FIG. 5.—A ball breaker.

series of trays with movable bottoms, on which the moist tea leaves are exposed to a blast of heated air forced up through the apparatus.

As conducted at Pinehurst, the operation consists of spreading the leaf on the sliding top tray of a 42-inch drier and pushing it into the drying box, where it meets a current of heated air (230° F.), which is drawn through the apparatus by a powerful fan. After a minute or two it is dropped through the turning slats of woven-wire cloth, which constitute the floors of the trays, onto the tray immediately below. This is done three times, by which time, three or four minutes after the beginning of the firing, the greater portion of the moisture in the leaf has been dissipated. Then the top tray is loaded with another charge of wet leaf and shoved into the drying box and

the first charge dropped on the bottom tray to remain there until it feels only slightly moist to the hand. By this system the leaf with the larger content of water is introduced into the top of the drying box and the moisture borne away without being condensed on any leaf above it. The leaf here loses its soggy condition quite rapidly, a state always regarded as destructive of flavor, and very little moisture rises from it by the time another tray is introduced above it. Although only two of the five trays are in use at any time, the more rapid dissipation of the moisture by this process prevents the protraction of the total time required to finish the firing. By using the

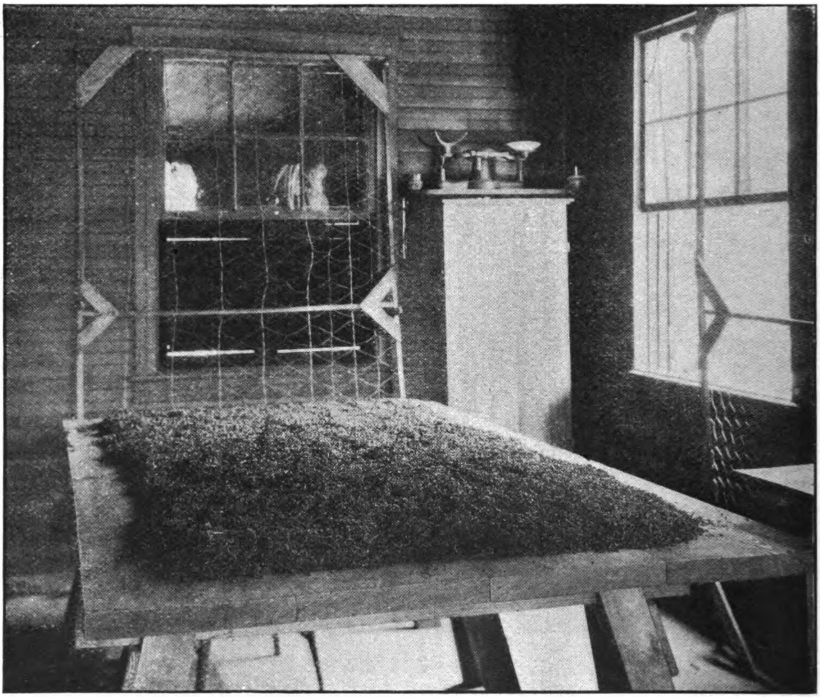


FIG. 6.—Method of oxidizing the rolled leaf. The wire screens when put into position hold up the damp cloths.

common method of employing all the trays at the same time the moisture escaping from the lower ones must necessarily suffer condensation in the upper trays, and the leaf on the upper trays will remain soggy until it has been shaken through to the lower ones. This tendency is aided by the fact that in its passage through the wet leaf the temperature of the current of air falls from an initial heat of 230° to less than 150° F. at its point of exit. The imperfectly dried leaf is then transferred to a 72-inch drying machine of similar construction, where it is subjected on successive trays to a current of air heated to 190° F. until perfectly dry and brittle. Experience with

this system of firing has demonstrated a satisfactory development of the desired cup qualities and style in the dry tea.

GREEN TEA.

In making green tea the oxidative fermentation process, through which the characteristic color and flavor of black tea are produced, must be inhibited as completely as possible. This reaction requires three things: An oxidizing enzyme or ferment, the oxygen of the air, and a substance upon which the oxygen acting under the influence of the enzyme reacts. Whenever a tea leaf is crushed or the cells broken in any other way and then exposed to the air, a browning of the leaf takes place, due to the occurrence of this reaction in the injured tissues, and the enzymes and other substances react in the presence of the air to produce dark-colored substances. In making black tea this oxidizing reaction is facilitated. It has been ascertained by technical laboratory studies that this reaction may be conveniently suppressed by destroying the enzyme, heat being the most available agent for doing this.

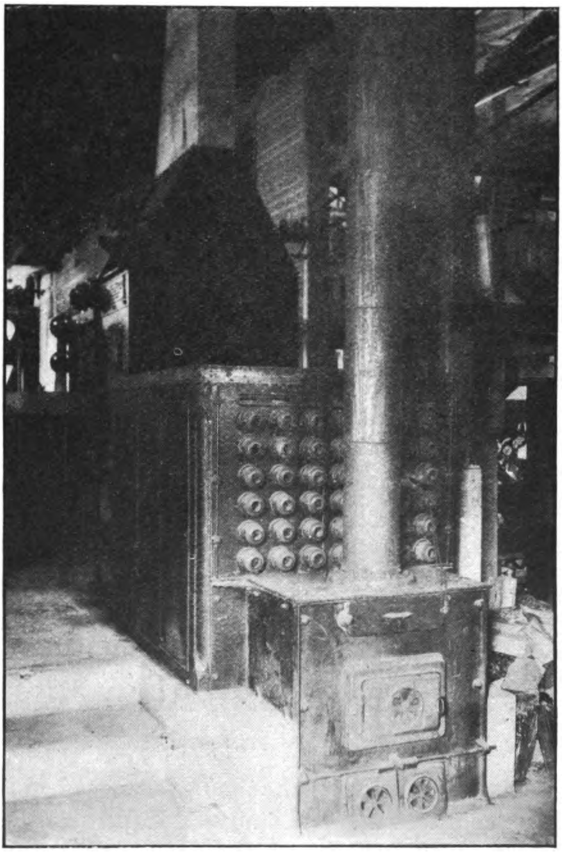


FIG. 7.—Furnace end of drying machine.

When green tea is made, the first step taken after the leaves are plucked aims to destroy the oxidizing enzymes and prevent the reaction referred to. Various methods of accomplishing this purpose are in use in many parts of the tea-producing area. Heating in pans or baskets is practiced in China and Japan, while the same object is

sought in India and Ceylon by steaming the leaves in a closed space. In the former case only small quantities of tea can be prepared at a time, since the process requires much labor and manual skill and the results are occasionally imperfect. In the steaming process the cooking of the leaf frequently causes a loss of aromatic and other valuable constituents.

A machine (fig. 8) has been designed by Dr. Shepard to do the sterilizing, and very favorable results are obtained with it. This machine consists of a horizontal rotary cylinder about 12 feet long with spiral flights on the inside that cause the leaves to fall several hundred times through its full diameter (20 inches) during their passage through the cylinder. At 14 revolutions to the minute it takes

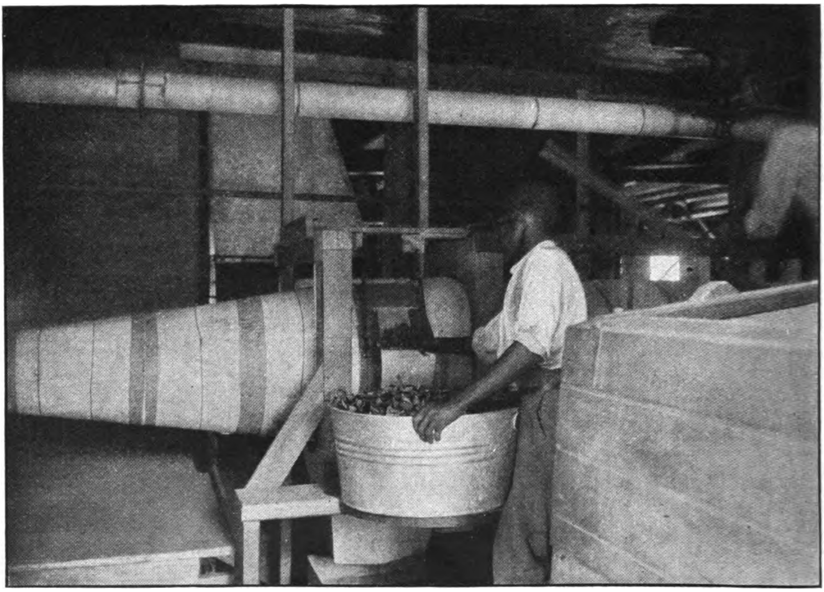


FIG. 8.—Loading end of sterilizer.

about seven minutes for the leaf to pass from the feeding doors, where it encounters a current of air heated to from 550° to 600° F. drawn through the cylinder by a fan, to the discharging end where the temperature of the air does not exceed 212° F. The leaf is here delivered in a flaccid condition suitable for rolling and free from the active oxidizing enzymes. After rolling and "ball-breaking" it is ready for the firing machine. It is first fired at 230° F. until the excess of moisture is driven off and the roll feels gummy. Then it is rolled for 20 or 30 minutes under pressure, where it takes on a very tight twist. The firing is then completed at 190° F.

Although it is agreed by all writers on tea that the leaf for making green tea should be immediately manufactured, the present writer

has obtained excellent results by carrying over the leaf picked in the afternoon until the next morning before passing it through the machine. To accomplish this the leaf is spread about 6 inches deep in a cool room and the edges swept around so that no stray leaves may become withered. Leaf picked in the evening and carried over successfully appears to give a greener product than that picked and manufactured the same morning.

"SHELTER" TEA.

An interesting experiment has been made at Pinehurst in raising tea under shelter sufficient to protect the plants from the direct sunlight. It is also done in Japan, where the finished product is styled "sugar" tea and is highly appreciated, commanding an extra high price. The content of thein is very large and that of tannin quite small as compared with other teas. The leaves attain a very large size, are quite silky, and assume a decided blue color. The cup qualities are excellent, being delicate in flavor, free from astringency, and fairly fragrant.

At Pinehurst a garden of two-thirds of an acre has been covered with a frame, elevated so that the mules may plow under it, and spread with a rather open wire mesh on which the screen is placed. At first a covering of matting was used, which was rolled up at nightfall and spread in the morning during the development of a flush, but kept rolled up for a few days after the tea had been gathered. This proecdure was too expensive in labor and now pine straw spread over the woven wire is kept in place during the whole of the cropping season. Nevertheless, in view of the small yield, the cost of production is high, although the finished tea readily brings $5 a pound.

FINISHING PROCESSES.

Equalizing and sorting.—When tea comes from the firing machine the rolled leaves exhibit the same differences in length as when fresh from the gardens. In India and Ceylon the tea is "equalized," that is, passed through a machine which cuts the leaves to a product of fixed maximum size, after which the tea is sorted for the market by a series of sieves. The dust is taken out by the first sieve and the grades are separated in order of fineness, as follows: "Broken orange pekoe," "broken pekoe," "pekoe souchong," "souchong," etc. The method of sorting and grading the leaf at Pinehurst is essentially different from that generally practiced in India and Ceylon in that the cut leaf is not put with the highest grade, which has passed through the sieve without being cut. Thus the dried leaf is screened without a preliminary cutting and yields "fines," to which no part of that which could not pass through the screen is added. The second

quality is the product resulting from cutting and screening that portion which after cutting passes through the screen which separates the "fines." The third portion embraces all that could not pass through at the second screening. It is passed through the cutter until all the tea has been reduced to the requisite size. In other words, the cutting of an inferior large leaf does not entitle it to enter the the market as the equal of the originally smaller and superior leaf.

Attritionizing.—The very fine green teas of China and Japan receive their natural greenish color by rubbing in a warm pan for about an hour after the completion of the ordinary firing, but this

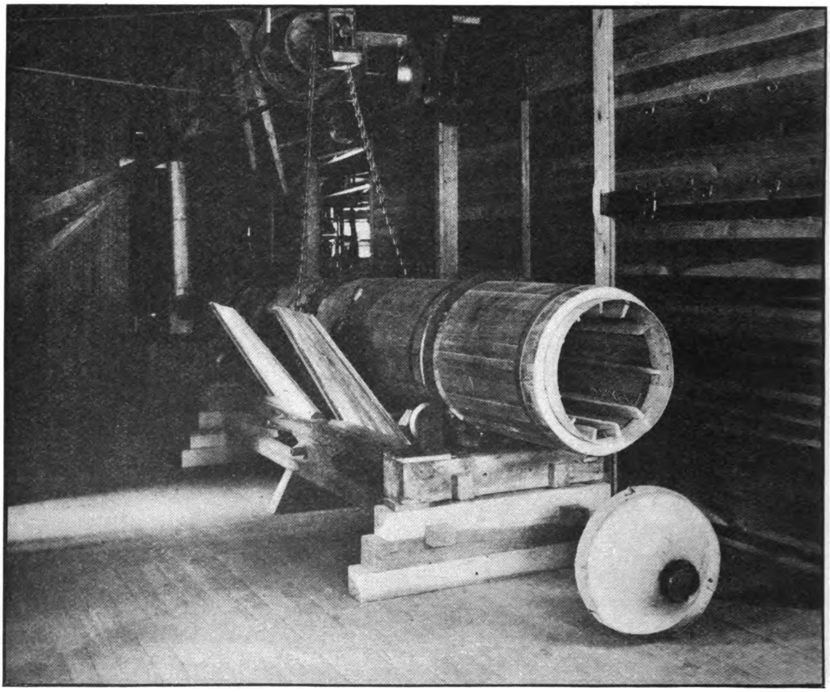


FIG. 9.—Attritionizer.

greenish tint of the "natural colored" tea did not satisfy the demands of the American market. To meet the desire for a more highly colored green tea, materials have been very generally added to oriental tea just before the completion of the firing in the form of a mixture of indigo or Prussian blue, turmeric, and soapstone, although usually in too small quantities to prove deleterious to health.

At Pinehurst the green teas are polished or colored without the addition of extraneous substances. It was observed that when dry tea was persistently stirred the friction of the tea leaves on each other developed the desired finish. A machine, called the attritionizer (fig. 9), was developed by Dr. Shepard in which this principle

was so worked out as to permit the finishing of tea on a large scale. It consists essentially of a revolving horizontal cylinder in which the tea is kept in motion in a current of air previously heated to a point not to exceed 180° F. This process requires from two to three hours and owing to the slight demand on the power is performed with but little cost.

Culling.—With the strictest superintendence small pieces of twigs and undesirable leaves will escape the notice of the inspectors. After the tea is otherwise finished these pieces are easily noticeable and the larger pieces have to be culled out by hand. This culling is generally done by girls and costs from a half cent to 1 cent a pound.

Dusting.—The last stage in the finishing process is that of dusting. During this operation the fine dust is blown out and the "broken" or "ragged" tea is separated from the rolled leaf. This operation improves the "style" of the product more than any other process, because the discolored pieces generally consist of coarse particles and leaves too tough to take on a roll, and they subsequently get broken into small, flaky pieces.

STORAGE.

The bins should be located in a separate room in the factory near the furnaces, so that the air in this room will be as nearly dry as possible. The rooms should be two stories high and the bins located on the sides against the walls, with a passageway between the rows. They should extend from the upper story, where the tea is put in, to within about 3 feet of the floor of the lower story. The bottom of the bins should slant and be provided with sliding doors for discharging the tea. The bins should be either zinc lined or made of two thicknesses of well-seasoned boards, with odorless building paper between them. The inside lining of boards should be tongued and grooved and should extend up and down, so that the tea may not lodge in the cracks. The bins should be of various sizes to prevent space being lost by differences in bulk. They should be kept locked by the manager or some competent person, to prevent any chance of mixing the different grades. Before being placed in the bins, each day's output should be tested and approved, as otherwise a small quantity of inferior tea might ruin a whole bin.

CONCLUSIONS DEDUCED FROM EXPERIENCE WITH TEA CULTURE AT PINEHURST.

The quantity of tea produced varies and is influenced by the seed, soil, climate, cultivation, pruning, plucking, and many other causes; but one fact must be borne in mind and that is that, no matter to what it is due, a large production seems to be made always at the expense of the quality of the product. This is not only the experi-

ence abroad, but is also true at Pinehurst. A slow development of leaf generally goes with a choice tea of high flavor.

Since the experiment was begun with the intention of acquiring information as to the possibility of producing commercial tea profitably in this country, it was necessary to extend the experimentation over as great a variety of soils and with as many kinds of seed as possible. The variation in the soils at Pinehurst made it an excellent place for obtaining this information. In procuring the many varieties of imported seed, aid was given by the Chinese and Japanese Governments by furnishing exceptionally valuable seed. Other consignments of seed were procured by the United States consuls and by purchase and gifts from many other sources. The plan of thoroughly testing the varieties of seed and their adaptability to different soils has been continued up to the present time, and, although many failures have been met and large expenditures incurred, much has been learned relative to the methods of seed and soil selection, cultivation, and manufacture that will be of material value to those who may embark in the business hereafter. Owing to the tentative nature of the work at Pinehurst, much money was spent in experimentation that can not justly be included in the expense of producing the commercial article.

As in India, Ceylon, and Java, large areas must be planted in this country in order to insure a profitable investment in tea culture, the relative cost of production decreasing as the acreage increases. Using the methods of selection, cultivation, and curing which have been developed at Pinehurst, it seems possible to estimate the profits that may properly be anticipated from a plantation of 200 acres or more. It should be borne in mind that economy of production demands the employment of special and generally expensive machinery, that its successful use requires the attention of skilled labor, and that when both are kept busy the cost of the output per pound will be cheaper. Again, the systematic superintendence of the gardens and factory and the general management of the business require intelligence and constant application. Under these circumstances, the establishment and maintenance of a commercial tea estate assume the proportions and pecuniary necessities comparable to those of a cane-sugar or beet-sugar project.

Before any outlay is incurred, and after a thorough investigation, a careful decision should be reached as to the character of the output of the tea and the means of disposing of it, as future success will largely depend on the correctness of the judgment in these matters.

Equally important is the selection of a suitable location. The requirements for the latter are fertile, cleared, well-drained, and rather level land and abundant cheap laborers, especially women and children. The location should be healthful, admitting of the

residence of the manager on the estate during the summer season, and transportation should be cheap, with easy access to the contemplated market. Especial care should be exercised that the gardens be established on a rich, deep, loamy soil, so that no necessity shall arise for the application of expensive enrichments, especially commercial fertilizers, which in themselves are liable to consume what otherwise might be a profitable return on the undertaking.

It is to be remembered that a tea garden with a production of less than 250 pounds to the acre can hardly prove remunerative, and that perhaps seven years may elapse from the planting of the seed until this rate of yield is obtained. On the other hand, the proper installation is for a very long term of years. According to presumably accurate information there are in the Orient some gardens in which the original bushes have continued to produce excellent tea for several hundred years, and it is beyond all doubt that in India and Ceylon there are gardens which have steadily yielded profitable crops for 25 years and perhaps longer.

COST AND PROFIT OF TEA PRODUCTION.

Bearing in mind the lessons coming from the Pinehurst experiment, the writer has prepared an analytical estimate covering the financial prospects of the would-be tea grower establishing himself in the Southern States. A working capital of at least $50,000 must be available for the purchase of adequate real estate and equipment and to meet other necessary expenses to be incurred before the income from the operation becomes sufficient to bear them. The area to be used for tea growing should not be less than 200 acres. When the tea estate contains less than this area it is presumed that the proprietor will manage it with the help of a qualified foreman. In this estimate no charge is made for superintendence. The remuneration of a first-class tea superintendent would absorb too large a proportion of the gross profits unless the estate covered more than 200 acres. When one reflects on the difficulty of disposing of a new variety of merchandise, the necessity for considerable expenditure in advertising or its equivalent is very evident—another reason for enlarging the crop area so that the cost of distribution may be diminished.

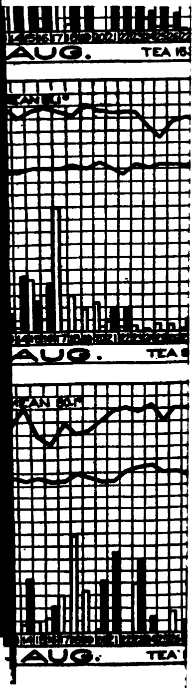
Table IV, based on the data secured at Pinehurst, has been prepared to show the estimated expenditures for the purchase of land, erection of factory and farm buildings, cost and maintenance of mules, and the various field and factory operations. It does not include the cost of management, taxes, fire insurance, or possible outlays for advertisements, and presupposes the selection of sufficiently fertile lands to obviate, at least for many years, the purchase of any commercial fertilizers.

TABLE IV.—*Estimated expenditure and income of the first 10 years on a tea pl of 200 acres.*

Items.	First year.	Second year.	Third year.	Fourth year.	Fifth year.	Sixth year.	Seventh year.	Eighth year.	Nint year
Unreturned expenditures brought forward	....	$20,000	$25,650	$36,195	$39,079	$39,415	$36,524	$28,781	$18,14
Interest at 7 per cent	....	1,400	1,795	2,534	2,736	2,759	2,557	2,015	1,27
Purchase of land and erection of buildings	[1] $15,000	....	[2] 5,000	....	....	2,000	....	....	....
Plowing[3] and hoeing	....	500	1,500	1,500	1,250	1,000	800	800	80
Purchase and upkeep[4] of mules	2,500	500	[5] 2,000	500	500	500	500	500	50
Supplies and incidentals	1,000	250	250	250	250	250	250	250	25
Nurseries and transplanting (American seed)	1,500	3,000	....						
Pruning	....	....	....	[6] 300	[6] 300	[7] 400	[7] 400	[8] 500	[8] 5
Plucking leaf	....	....	....	[10] 400	[11] 700	[12] 1,400	[13] 1,750	[14] 2,100	[14] 2,1
Factory	....	....	....	[15] 400	[16] 600	[17] 800	[17] 1,000	[17] 1,200	[17] 1,2
Total outlay	20,000	25,650	36,195	42,079	45,415	48,524	43,781	36,146	24,7
Sales of tea at 30 cents a pound	....	....	....	3,000	6,000	12,000	15,000	18,000	18,0
Indebtedness	20,000	25,650	36,195	39,079	39,415	36,524	28,781	18,146	6,7
Profit after liquidation of investment	....	....	....	....	....	....	....	....	....

[1] Land, $10,000; farm buildings, $2,500; cleaning up, ditching, etc., $2,500.
[2] Erection of factory, $5,000.
[3] The expense for plowing includes the feed for mules while so engaged. It is calculated th extra land will be included in the purchase of the plantation to provide ample feed for the mu
[4] The item of upkeep for mules is meant to cover wages of plowmen when employed in other cultivation. The increase in mules is not accompanied with additional expense in upkeep, as devoted thereto should afford larger returns under continued cultivation.
[5] Purchase of additional mules, $1,500.
[6] Pruning, at $1.50 per acre.
[7] Pruning, at $2 per acre.
[8] Pruning, at $2.50 per acre.
[9] Pruning, at $3 per acre.
[10] Plucking 50 pounds dry tea per acre, at 4 cents per pound.
[11] Plucking 100 pounds dry tea per acre, at 3½ cents per pound.
[12] Plucking 200 pounds dry tea per acre, at 3½ cents per pound.
[13] Plucking 250 pounds dry tea per acre, at 3½ cents per pound.
[14] Plucking 300 pounds dry tea per acre, at 3½ cents per pound.
[15] Factory work, at 4 cents per pound.
[16] Factory work, at 3 cents per pound.
[17] Factory work, at 2 cents per pound.

It will be observed that the annual production, gradually ris 300 pounds of dry tea per acre, valued at an average selling p 30 cents a pound, suffices in 10 years from the starting of the prise to liquidate the entire investment (with certain except but when it is remembered that some of the Pinehurst tea ga have produced at a much greater rate, the estimate of 300 po may be regarded as quite conservative. If, in and after the year, instead of using the total proceeds from the sale of te extinguishing the indebtedness of the estate, $6,000 be taken y as a dividend, the entire investment may be cleared in 16 y With the obligations paid, the plantation should bring in an a income of at least $10,000 for an indefinite period. If the gar embrace 400 acres, the cost per pound of finished tea shoul materially lessened and the total profit of the estate much than doubled.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It is apparent from the experience of tea planters in other parts of the world that the most influential factors with which one has to deal, apart from soil characters, are the rainfall and prevailing temperatures. It was recognized that carefully kept records of these conditions when correlated with the tea yield would be certain to give results of the utmost practical importance. Accordingly, such records were kept, and the results of the observations of seven years are presented graphically in the accompanying chart, figure 10. This chart shows the relation of temperature and rainfall to the production of tea in twelve of the gardens at Pinehurst during this 7-year period. The computations are given for each day. The upper irregular lines show the maximum temperature; the lower irregular lines, the minimum temperature; the closed columns, the production of dry tea in pounds; and the open columns, the rainfall in inches.

Table V describes these twelve gardens and the yield of tea. Since the gardens were situated on widely varying soil types, the record of each was kept separately, thus providing a test of these different types of soil conditions. It is clear that during this extended period the gardens have had time to pass through various stages of maturity, a fact which influences somewhat the interpretation of the results. As the gardens here enumerated form but a portion of the tea area of Pinehurst, it must be borne in mind that the totals given do not indicate the entire output of Pinehurst at any time.

TABLE V.—*Description of tea gardens included in the study of tea production in relation to temperature and rainfall.*

Names of gardens.[1]	Variety of tea plant.	Character of soil.	Area.	Date of first plucking.	Production of dry tea.							Fertilizer[2] (200-pound sacks).						
					1901	1902	1903	1904	1905	1906	1907	1901	1902	1903	1904	1905	1906	1907
			Acres.	*Year.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*							
Old Rose	Assam hybrid	Rich sandy loam; a subsoil-drained piny-woods pond.[3]	0.89	1892	309	392	375	323	429	342	277	4	4	4	5	6½	5	3½
North Bottom	do	Fertile sandy loam; quite sloping	2.66	1892	243	435	268	366	505	481	402	6	8	7	6	6	6	6
South Bottom	do	Part loamy bottom; part clayey upland.	3.78	1893	278	388	437	412	338	422	335	5	5	6	8	6	6	5½
Field's Hedges	do	Part quite sandy; part drained rich piny-woods pond.[3]	4.11	1898	246	652	597	367	557	724	485	10½	12	6	5¾	7	6⅔	6
Indo-Ceylon	do	Thin sandy loam on clay	7.29	1896	428	787	908	686	671	799	395	10½	12	13¾	16½	24⅓	12	10
North Fraser	do	Very sandy and poor soil	2.50	1898	163	309	322	217	304	275	181	6	8	7	7¼	6	6	4
South Fraser	Dragon's Pool Chinese.	Rather sandy loam on good clay subsoil.	2.00	1894	186	504	410	281	339	690	475	7	8	7	9⅓	9	8½	6
Young Chinese No. 2.	do	Part sandy loam on hillsides; part rich bottom.	3.67	1899	172	406	521	406	437	708	568	0	0	6	6¼	8	8⅓	8
Lincoln Pond	Darjeeling	Rich piny-woods pond; well drained[3]	1.90	1896	347	554	502	504	620	660	639	4	4	4	5	5	5	5
North Fortune	do	Quite sandy and thin soil; high elevation and dry.	8.15	1898	508	866	824	834	1,008	1,052	574	11	12	15	15½	23	16	15
South Fortune	do	Drained piny-woods pond; rich in center, poor on edges.[3]	3.00	1898	289	446	448	432	594	669	566	3	4	4⅓	5	5	5	5
King Lot	Mixed	Sandy, much interspersed with trees.	6.63	1894	198	369	339	269	282	418	181	10	10	13	·14	10½	10½	3

[1] In selecting the gardens for comparison it was sought to present an average of the conditions here prevalent, i. e., both good and poor soil, as also low, moist locations and high, dry locations. Attention is especially called to the exceptionally large production of tea in 1902 and 1906, when abundant rainfall and high temperatures prevailed during the cropping season. These conditions and rather severe pruning influenced the quantity of yield more than an increase in the fertilizer applied, although the table exhibits a few instances due to the last cause, viz, Old Rose in 1905, South Bottom in 1903, and North Fortune in 1905.

[2] The fertilizer contains 4 per cent each of available phosphoric acid and potash, K_2O, and yields same amount of ammonia (from dried fish and dried blood).

[3] See description on following pages.

CONDITIONS IN THE GARDENS.

Since the gardens under study represent widely varying conditions, it is necessary in order to enable the reader to properly interpret the results to give a brief discussion of each garden.

Old Rose Garden.—The site of this garden was formerly a piny-woods pond. The soil is a rich, sandy loam, thoroughly subsoil drained. This Assam-hybrid garden has yielded at the rate of over 400 pounds of dry tea to the acre during the past eight years. Previous to the spring of 1899, when the thermometer fell to $-\frac{1}{2}°$ F., the plants had developed into comparatively small clumps, but in consequence of that freeze it became necessary to cut them off to the ground, by reason of which, and an equally severe pruning in the spring of 1907, the clumps each consisted of 50 or more vigorous shoots and in each instance showed a notable increase of production the second year thereafter. Cowpeas have been regularly planted in the rows and plowed in when grown. The garden is 16 years old and most vigorous.

North Bottom, or Swamp, Garden.—This garden lies on land sloping 2 to 3 feet to the hundred from the first sandy plateau to the swamp level; consequently, rains and water from the lands in the rear washed off a great deal of the topsoil, depositing it in the ditch and swamp at its lowest level and leaving many of the tea plants on cones of the topsoil held in place by the roots of the bushes. The soil was restored to a considerable extent and is now held in place by a series of embankments, which are gradually forming terraces in the garden. The first effect of the replacement of the soil was to deprive the roots of a large part of the benefit of the dews and light showers, but owing to the spreading of the rootlets upward an improvement is noticeable. The yield of the bushes, which are generally large and thrifty, was not satisfactory, however, and they were pruned severely in the spring of 1909 in the expectation that the production would be notably increased. The soil is a light sandy loam.

South Bottom, or Swamp, Garden.—This garden consists partly of low, flat, rather rich sandy-loam soil and partly of thin, sandy topsoil overlying clay on a hillside which required terracing. Pecan trees are on both soils and the Pinehurst experience opposes such contiguity. The garden has not produced the quantity of tea expected. The lower portion has been liberally treated with complete fertilizers and barnyard manure applied in trenches between the tea rows. It is possible that the subsoil was not sufficiently drained and that the pecan trees operated disadvantageously, but the falling off in production was more probably due to the lack of severe pruning for several seasons. It was heavily pruned back and the soil freely enriched during the spring of 1909. The bushes are now in good form and show very few breaks in the rows.

Field's Hedges Garden.—Field's Hedges Garden consists partly of a drained lowland, formerly a piny-woods pond, with very rich alluvial soil in which the tea hedges exhibit great luxuriance and each autumn almost cover the entire surface. The rest of the soil is sandy upland, which at the beginning of cultivation was almost sterile. Free enrichment with barnyard and commercial manures, the cultivation of cowpeas between the rows, and severe pruning (notably in 1904) have done much to improve the soil and the crops.

Indo-Ceylon Garden.—This garden lies mostly on high, sandy land with pecan trees through the greater part of it. It was planted with seedlings from Assamese and Ceylonese seed, but they were not hardy enough to withstand the climate and were replaced with the tea that resembles the eastern Assam-hybrid and that is virtually hardy by reason of long cultivation in this country. The poverty of the soil and the presence of the pecan grove have so reduced the production that it has been determined to destroy the tea bushes and subject the land to a thorough treatment by green manuring. Seed obtained from greater elevations than 5,000 feet in Ceylon is capable of attaining excellent growth in this climate, as large gardens of the same in other locations at Pinehurst abundantly demonstrate.

North Fraser Garden.—This garden, too, has demonstrated the uselessness of attempting to raise tea profitably on high and sandy lands. The cost of applying sufficient enrichment to produce fairly remunerative crops for a few years proves later inadequate, as the stock of humus in the soil is depleted, despite even the introduction of legumes between the rows and frequent severe pruning. Under these circumstances it is well to abandon the cultivation of tea on such worn-out land (as is often done in the Orient) or, better, to restrict the establishment of tea gardens to rich lands whose fertility may extend over many years.

South Fraser Garden.—The South Fraser Garden lies mostly on a slightly elevated hill and has a sandy loam resting on a rather rich, clayey subsoil. The bushes were grown from seed furnished by the Chinese Government from the celebrated Dragon's Pool tea estate. They are dwarfish, but although planted 4 feet apart almost cover the ground. The leaf is generally small, but affords most delicate green tea and yields to the extent of over 300 pounds to the acre in favorable seasons when the temperature is high. The garden has been freely enriched with both stable and commercial manures, but an occasional severe pruning is indispensable for the maintenance of thrifty growth.

Young Chinese No. 2.—This garden occupies the bottom and sides of a rather shallow ravine. The former has a rich, deep, loamy soil; the latter is somewhat sandy, underlain by a rich clay subsoil. The plants come from the Dragon's Pool stock and in the bottom attain a

large size, perhaps because of the greater humidity of the soil. By more abundant fertilization and more severe pruning a larger yield may be expected without impairing the quality of the tea. The greater heat and abundant rainfall of 1906 materially increased the output. The bushes are larger than those from the original imported seed, perhaps in part the result of hybridization, but the tea made therefrom does not exhibit any deterioration.

Lincoln Pond Garden.—This was the site of a piny-woods pond. It was thoroughly subsoil drained and planted with seedlings raised from seeds that came from the Pashok tea estate in Darjeeling on the slopes of the Himalaya Mountains in British India. This variety of leaf can be made into either a black or a green tea quite rich in flavor, yet delicate. On the rich soil of the old pond and without much enrichment it readily yields at the rate of over 300 pounds of dry tea to the acre.

North Fortune Garden.—North Fortune Garden is on a high, dry, and sandy hill. As the thin surface soil became exhausted, the annual crop of tea diminished to such an extent that it appeared wise to discontinue its use for a tea garden; but increasing its fertility by summer and winter legumes, stimulated by acid phosphate and kainit, has given excellent results at Pinehurst. Had this garden been nearer to the cattle barns, an attempt to enrich it with farm manure would have been made.

South Fortune Garden.—This garden is situated where once lay a piny-woods pond, the center having a deep, rich loam, but the soil on the surrounding slopes is decidedly sandy. The pond proper is subsoil drained. In 1903 after an unusually heavy rainfall the main drain became clogged and before the water could be removed from the roots a considerable number of the best tea bushes in the center of the garden perished. Wherever subsoil drainage is maintained by open-joint tile pipes it is absolutely necessary to keep the overlying earth free from thirsty tree and shrub roots; otherwise they will clog the pipes and in two or three weeks can kill the tea plants if the subsoil water is stagnant that long.

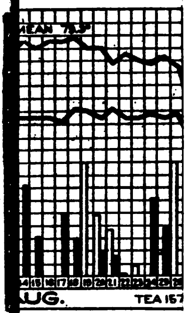
King Lot Garden.—This garden occupies the intervening spaces in groves of yellow pines and pecans. The soil is sandy and unpromising for the profitable production of tea. Nevertheless, it was planted with tea bushes partly as an ornament to the Pinehurst park and partly to prevent the growing up of unsightly or detrimental bushes. It is probable that the output of tea covers the cost of keeping the ground clear of the undesirable bushes. This garden was included in the list of those shown on the chart, as it was designed to present an average of many conditions and results in gardens which were in bearing previous to 1901.

CONCLUSIONS DEDUCED FROM A STUDY OF THE GARDEN

As a result of the experiments with the 12 gardens at Pinehu one of which was established without reference to possible remun ative yield, 3 have proved that the successful production of co mercial tea upon a sandy soil devoid of humus is practically imp sible. Half of the remainder have averaged 250 pounds of dry to the acre during the last four years of the period, and the oth are not far behind them. This lesson has been duly appreciated all subsequently installed gardens have been planted on richer moister land. So fertile have been some of them that there appea no necessity for applying enrichment to them, as has been dem strated by the following returns from comparatively young and un nured gardens, namely, Formosa, 412 pounds of dry tea per a Chinese, 314 pounds; Darjeeling, 315 pounds; Assam-hybrid, pounds; and Kangra, 253 pounds. With a yield of 250 pounds dry tea to the acre, the cultivation of tea at Pinehurst becomes re nerative although burdened in some instances by an expenditure $6 per acre for commercial fertilizers. At 400 pounds to the acr can not fail to be quite profitable.

In addition to the records showing the performance of selec gardens, the records of rainfall, temperature, and total tea yield the entire estate have been prepared for the period of three ye from 1908 to 1910, inclusive. These relations are shown in accompanying chart, figure 11. The records cover each day. upper irregular lines show the maximum temperature; the lo irregular lines, the minimum temperature; the closed columns, production of dry tea in pounds; and the open columns, the ra fall in inches. It will be noticed that the temperatures for 1 were very low, especially in May, which is probably the cau of the very poor crop for that year. In 1909 a fairly large cr was produced, due to rather high temperatures and a very regu distribution of the rainfall during the plucking season. T diminished production in 1910 was caused mainly by a strike the laborers during the pruning season, which interfered with th pruning of some of the gardens. The very low maximum temper ature, the severe drought early in the spring, and the fact that the plucking extended only to September 8 combined to reduce materially the production of tea for the season of 1910. The quality of the tea for 1910 excelled that of any previous year on account of the slow development of the leaf and the early cessation of plucking.

Figure 11 is especially interesting, as it includes one year (1909) of fairly ideal weather conditions for tea growing. The other two years, 1908 and 1910, show how much the production might be reduced by either unfavorable weather or labor conditions.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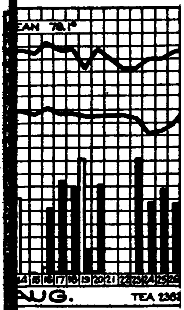
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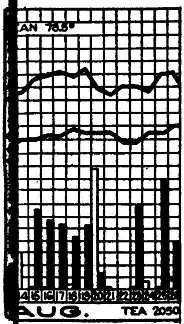
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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 235.

B. T. GALLOWAY, *Chief of Bureau.*

WILD VOLATILE-OIL PLANTS AND THEIR ECONOMIC IMPORTANCE: I.—BLACK SAGE; II.—WILD SAGE; III.—SWAMP BAY.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 14, 1911.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 235 of the series of this Bureau a manuscript prepared by Mr. Frank Rabak, Chemical Biologist, entitled "Wild Volatile-Oil Plants and Their Economic Importance: I.—Black Sage; II.—Wild Sage; III.—Swamp Bay," submitted by Dr. R. H. True, Physiologist in Charge of the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.

At present the various industries making use of volatile oils and their derivatives find their supply of these materials in products obtained from Old World plants grown in foreign lands. In some cases, because of the difficulty in producing these substances, it is likely that this commercial situation will persist for some time, but in other cases it seems likely that American resources may be capable of utilization. In our wild flora there are many oil-containing plants of considerable commercial promise and the purpose of this bulletin is to bring to notice the results of investigations which have been carried on with a number of these plants and to point out their commercial utility. It is presented as the first of a series, to be followed from time to time with the results of further investigations which are to be carried on with this class of plants and their products.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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WILD VOLATILE-OIL PLANTS AND THEIR ECONOMIC IMPORTANCE: I.—BLACK SAGE; II.—WILD SAGE; III.—SWAMP BAY.

DISTRIBUTION OF WILD AROMATIC PLANTS.

There exists in the flora of the United States a large number of plant families which include species of highly odorous character, many of which are known and described botanically as possessing peculiar aromas, but which have received no attention from the standpoint of their volatile-oil content. The various sections of the country, with their marked differences of soil and climate, possess floras peculiar to themselves which, if investigated, would doubtless reveal many plants valuable for their volatile oils. For example, in Florida and the South Atlantic States are found many plants with agreeable odors which thrive only in the climate and soil of that region. The Central Western States produce numerous species of sages and other plants found only in arid and semiarid climates. In the extreme Western States are numerous wild aromatic plants, some of which have been distilled and analyses made of the oils obtained therefrom.

PRESENT PRODUCTION OF VOLATILE OILS FROM WILD PLANTS NATIVE TO THE UNITED STATES.

Only a very few of the wild plants native to this country have been distilled and their volatile oils used for commercial purposes. Among these may be mentioned longleaf pine, sassafras, wintergreen, sweet birch, pennyroyal, horsemint, and Canada fleabane.

The first and by far the most important oil distilled from a wild plant indigenous to the United States was turpentine oil, which was distilled as early as the middle of the eighteenth century. The production of this oil is rapidly declining, owing principally to the employment of very wasteful methods, which have resulted in the destruction of many of the large pine forests. Turpentine is still obtained, however, from the longleaf pine (*Pinus palustris*), which occurs quite abundantly in the South Atlantic States from Virginia to Florida. The price of this valuable oil has risen so rapidly in recent years, owing to the shortage of raw material from which it is distilled, that a suitable substitute would be most desirable. This

problem is now receiving the attention of scientific research workers, but no satisfactory substitute which can supply the trade has yet been found.

The commercial distillation of sassafras, wintergreen, and sweet birch possibly rank next in importance, although the oils are produced on a considerably smaller scale. These oils are used extensively by perfumers, confectioners, and manufacturers of toilet soaps. The plants are gathered in their native habitats and the quality of the oil depends upon the freedom from extraneous material, which can be insured only by extreme care in collection.

The production of pennyroyal and Canada fleabane oils from the wild plants is also carried on in a small way. The oils from these plants possess valuable therapeutic action and are used principally in medicinal preparations.

Horsemint and wild bergamot are wild aromatic plants which have been more recently distilled for their volatile oils. The use of these plants was brought about by the discovery that their oils contain, respectively, the valuable antiseptics thymol and carvacrol. The production of the oils, however, is not being carried on to any great extent.

These few species are practically the only wild aromatic plants of the United States which are at present being utilized for their volatile oils, and no attempt has yet been made to cultivate them in order to improve the quality or to increase the yield of the oils.

CLASSIFICATION OF VOLATILE OILS BASED ON THEIR ODORS AND CONSTITUENTS.

Volatile oils obtained from plants possess a great variety of odors, with no two exactly alike, although many are very closely related. A classification of these oils based on their odors is not satisfactory, since many which would not be considered as related if judged only by the sense of smell have chemical relationships, containing substances belonging to the same general class of chemical compounds. For our purpose volatile oils are divided into the following classes, basing the divisions upon odors and constituents. These groups comprise the majority of oils, but they are not arranged in the order of their importance:

(1) *Camphoraceous oils*, possessing a characteristic camphorlike odor, with camphor or camphor-related compounds predominating, as in the oils obtained from the camphor tree and from many of the sages. The products obtained from camphoraceous oils are extensively employed in the arts and in medicine.

(2) *Terebinthinate oils*, having a characteristic turpentinelike odor. These oils are obtained largely from the pine family, the turpentines of commerce being examples. They are composed largely of terpene

hydrocarbons and find extensive application in the paint and varnish industries.

(3) *Sulphur-containing oils,* a small group characterized by extremely disagreeable and offensive odors, such as those of mustard, asafetida, garlic, and onion. These oils contain as their chief constituents sulphids, sulphocyanates, or nitriles, and are used principally for medicinal purposes.

(4) *Phenol and phenol-related oils,* containing phenols or phenol derivatives and characterized by strong, persistent odors, some very pungent and others pleasant. Owing to their phenolic constituents the density of these oils is usually very high. Common examples of this class are the oils of thyme, cloves, cinnamon, sassafras, anise, fennel, and the monardas. The usefulness of phenol and phenol-related oils depends largely upon their antiseptic properties, the principal constituents being thymol, carvacrol, eugenol, anethol, chavicol, safrol, and their derivatives.

(5) *Oils containing esters or alcohols,* by far the largest group, consisting of the fragrant oils which are used principally for perfumery purposes, although some find a use in medicine. The chief constituents of these oils are usually alcohols and esters, some few containing aldehydes, ketones, oxids, and lactones. Prominent here are the alcohols menthol, linalool, geraniol, citronellol, sabinol and their esters, benzyl alcohol and its esters, and anthranilic acid and its esters, forming the chief constituents of the oils of peppermint, lavender, geranium and rose, citronella, savine, ylang-ylang, and orange flowers, respectively. Other constituents are the aldehydes citral and citronellal from lemon and lemon-grass oils, and the ketones thujone, menthone, pulegone, carvone, and methyl heptenone from the oils of wormwood, peppermint, pennyroyal, caraway, and rue. The oxid cineol from eucalyptus and many other oils, and the lactone sedanolid from celery oil are further examples.

All volatile oils capable of being isolated from wild aromatic plants will fall into one or more of the foregoing divisions although, it must be understood, the classification is far from being satisfactory. It will, however, serve to elucidate the fact that although plant odors are of a very variable character they still possess some relationship.

COMMERCIAL IMPORTANCE OF VOLATILE OILS AND THEIR CONSTITUENTS.

Not only do volatile oils as such find important uses in commerce, but the great variety of constituents, one of which in many cases forms the major part of an oil, find equally important uses commercially.

Such constituents as have antiseptic properties occur widely in plant oils and are of untold value to the medical profession, to the

manufacturer of pharmaceutical preparations, and to the maker of toilet lotions and dentifrices. Many volatile oils also contain constituents which are recognized as very important in the perfumery industries, their value depending not so much upon their own inherent odor as upon the effect which they produce in modifying or toning the fragrance of a mixture of several components. The finest perfumes are often mixtures of odors blended together and frequently contain oils which in themselves would not be regarded as very agreeable or pleasing in odor. In some instances a single constituent, as for instance citral, the chief constituent of lemon-grass oil, is used in its own pure condition without the admixture of other odors, as in the scenting of fine toilet soaps.

As flavoring agents considerable use is made of many of the volatile oils or of their constituents. For example, the oils of sassafras, peppermint, cinnamon, and wintergreen are used by confectioners in the flavoring of candies. The chief constituents of these oils (safrol, menthol, cinnamic aldehyde, and methyl salicylate) can, with the exception of menthol, be used with equal efficiency.

Many essential oils and the compounds isolated from them have proven highly useful in therapeutics, and enter into a number of medicinal preparations. Such constituents as menthol from peppermint oil, eugenol from clove oil, methyl salicylate from wintergreen and sweet-birch oils, thymol from thyme and horsemint oils, camphor from camphor oil, borneol from Borneo camphor oil, cineol from eucalyptus oil, and many others, comprise a group of medicaments which are indispensable.

From the foregoing account of volatile oils and their important constituents may be observed the possibilities which lie in this field of investigation. It is probable that a thoroughgoing examination of the wild flora of the United States would reveal the presence of volatile oils in many plants which at present are not known to yield volatile products. This possibility should stimulate the search for these products with a view to their commercial utilization.

PLANT SOURCES OF CAMPHOR, BORNEOL, AND CINEOL (EUCALYPTOL).

Owing to the presence in large quantities of the compounds camphor, borneol, and cineol in the oils to be described in this bulletin, the usual sources of these compounds are herewith presented, together with their commercial uses.

The occurrence of camphor in the vegetable kingdom as a component of volatile oils has been noted chiefly in such plant families as the Lauraceæ, Compositæ, Labiatæ, and Zinziberaceæ. The source of commercial camphor at present is the camphor tree, *Cinnamomum*

camphora (*Laurus camphora*), indigenous to Japan and Formosa. This tree has been introduced into the United States and experiments are now being conducted in Florida for the production of camphor, with some degree of success.

Two modifications of camphor occur in nature, the commercial variety, or dextrogyrate (rotating the plane of polarization to the right), and the levogyrate (having the opposite rotation). Comparatively few plants native to this country have been found to yield camphor. Whittelsey[1] has recently succeeded in isolating and identifying levo camphor in considerable quantities from the oil of a western sagebrush (*Artemisia cana* Pursh., family Compositæ). Camphor has been observed in the native plant *Sassafras variifolium* (*Sassafras officinalis*), a tree belonging to the family Lauraceæ. According to Power and Kleber,[2] sassafras oil contains from 6 to 8 per cent of dextro camphor. Traces of camphor have also been observed in tansy oil,[3] obtained from *Tanacetum vulgare*, a plant which is cultivated in the Eastern States for its volatile oil.

Borneol, or Borneo camphor, is closely related to camphor and possesses very similar properties. It is derived chiefly from the Borneo camphor tree (*Dryobalanops aromatica* (*D. camphora*), family Dipterocarpaceæ), and is found in crude crystalline condition in the natural cavities of the wood.[4] *Blumea balsamifera* (family Compositæ), a shrubby plant[5] native to India, also yields considerable quantities of borneol,[6] known to the natives as ngai camphor. The presence of borneol in plants native to this country is restricted to a few species, where it appears in the free condition only as a trace, being found more widely distributed as esters. It has been found in small quantities in the oil of red cedar (*Juniperus virginiana*),[7] and in thuja oil from the arborvitæ (*Thuja occidentalis*),[8] both trees being found abundantly in various sections of the United States. Small quantities have been found in the oils of other native plants, such as the goldenrod (*Solidago canadensis*),[9] Virginia snakeroot (*Aristolochia serpentaria*,[10] Texas snakeroot (*Aristolochia reticulata*),[11] Canada

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1 Whittelsey, Th. A New Occurrence of l-Camphor. Otto Wallach Festschrift. Göttingen, 1909, pp. 668–670.

2 Power, F. B., and Kleber, C. On the Chemical Composition of the Oil of Sassafras Bark and Oil of Sassafras Leaves. Pharmaceutical Review, vol. 14, 1896, pp. 101–104.

3 Schimmel & Co., Semiannual Report, October, 1895, p. 47.

4 Kremers, E. Borneo Camphor. Pharmaceutical Review, vol. 23, 1905, pp. 7–14.

5 The earlier name for this genus is Placus (Loureiro, 1790), the name Blumea being published by De Candolle in 1833.

6 Schimmel & Co., Semiannual Report, April, 1895, p. 76.

7 Ibid., 1898, p. 14.

8 Wallach, O. Untersuchungen aus dem Universitätslaboratorium zu Göttingen, XIV. 4. Ueber das Semicarbazon des d- and l-Fenchons und das Vorkommen von l-Borneolester im Thujaöl. Nachrichten der Königlichen Gesellschaft der Wissenschaften zu Göttingen, vol. 1, 1905, p. 11.

9 Schimmel & Co., Semiannual Report, April, 1897, p. 46.

10 Spica, M. Studio Chimico dell' Aristolochia Serpentaria: Nota Preliminare. Gazzetta Chimica Italiana, vol. 17, 1887, pp. 313–316.

11 Peacock, J. C. Volatile Oil of Aristolochia Reticulata, Nuttall. American Journal of Pharmacy, vol. 63, 1891, pp. 257–264.

snakeroot (*Asarum canadense*),[1] tansy (*Tanacetum vulgare*),[2] and sweet gum (*Liquidambar styraciflua*).[3] As its acetic acid ester, it occurs in the oils of a large number of species of pines and firs.

Borneol and camphor occur occasionally together in the same oils. Their association is not surprising, since the relationship of the two compounds is very close. By oxidation borneol is readily converted into camphor. The two compounds have been observed together in the oil of cardamon,[4] distilled from the seeds of *Amomum cardamomum;* also in the oil of rosemary, from the plant *Rosmarinus officinalis*,[5] and in spike oil, obtained from *Lavandula spica*,[6] the latter two belonging to the mint family.

Cineol, or eucalyptol, is found chiefly in the volatile oils from various species of the eucalyptus tree and is the principal constituent of many of these oils. The blue gum tree (*Eucalyptus globulus*), belonging to the family Myrtaceæ and introduced abundantly in the western part of the United States, furnishes a volatile oil of which more than one-half is cineol. Other important sources also are cajuput oil[7] and niaouli oil[8] from *Melaleuca leucadendron* (*M. viridiflora*), a plant indigenous to India. Only a few native aromatic plants are known to yield volatile oils which contain cineol and in only a very few cases has this constituent been found to be present in any quantity. It is known to occur in the oil of the California laurel, or mountain laurel (*Umbellularia californica*),[9] where it is present to the extent of about 20 per cent. Among other native plants in which cineol is known to occur in small quantities is the composite *Achillea millefolium*,[10] commonly known as milfoil or yarrow. Peppermint oil from *Mentha piperita*[11] and sage oil from *Salvia officinalis*[12] are said to contain small quantities of this constituent.

Camphor, borneol, and cineol are found in considerable quantities in volatile oils which have been distilled from three unutilized aromatic plants of the United States, which will be discussed fully in the subsequent pages of this bulletin.

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[1] Power, F. B., and Lees, F. H. The Constituents of the Essential Oil of Asarum Canadense. Journal of the Chemical Society, London, vol. 81, 1902, pt. 11, pp. 59–73.

[2] Schimmel & Co., Semiannual Report, October, 1895, pp. 46–47.

[3] Ibid., April, 1898, p. 53.

[4] Ibid., October, 1897, p. 12.

[5] Gildemeister, E., and Stephan, K. Beiträge zur Kenntniss der ätherischen Oele, VI. Archiv der Pharmazie, vol. 235, 1897, p. 585.

[6] Bouchardat, G. Sur l'Essence d'Aspic (Lavandula Spica). Comptes Rendus, Academie des Sciences, vol. 117, 1893, pp. 53–56.

[7] Wallach, O. Über die Bestandtheile einiger ätherische Oele. Justus Liebig's Annalen der Chemie, vol. 225, 1884, pp. 314–318.

[8] Bertrand, G. Sur la Composition Chimique de l'Essence de Niaouli. Comptes Rendus, Société des Sciences, Paris, vol. 116, 1893, pp. 1070–1073.

[9] Power, F. B., and Lees, F. H. The Constituents of the Essential Oil of California Laurel. Journal of the Chemical Society, London, vol. 85, 1904, pt. 1, pp. 629–639.

[10] Schimmel & Co., Semiannual Report, October, 1894, p. 38.

[11] Power, F. B., and Kleber, C. The Constituents of American Peppermint Oil, and a Method for the Quantitative Determination of Menthol. Pharmaceutische Rundschau, vol. 12, 1894, pp. 157-165.

[12] Wallach, O. Zur Kenntniss der Terpene und der ätherischen Oele. Justus Liebig's Annalen der Chemie, vol. 252, 1889, pp. 94–157.

COMMERCIAL USES OF CAMPHOR, BORNEOL, AND CINEOL.

As an article of commerce camphor is most useful, being employed extensively in the arts and in medicine. Its use in the arts is restricted principally to the manufacture of celluloid, a commodity which finds a great variety of uses. It also finds important uses in the manufacture of lacquers and pyrotechnics, in embalming, and, because of its odor, is used as an insectifuge. Camphor is also used to a great extent in medicine both for external and internal application, and enters into many pharmaceutical preparations.

Borneol, although closely allied to camphor, is much less used commercially in the United States, principally because of the difficulties encountered in its collection by the natives in Borneo and the Malay Archipelago. It would probably be used more extensively in this country if a sufficient supply could be obtained at reasonable prices, the high price of the article preventing its use for technical purposes.

Borneol is antiseptic and stimulant, and finds its main use in medicine, but is also in demand in the perfume industry, the esters being especially desirable. The acetic acid ester of borneol (bornyl acetate) is in fact the odoriferous principle of pine-needle odor. Borneol is used mainly as a base for the manufacture of bornyl acetate which is much used in the preparation of pine-needle odors by perfumers. It is in considerable demand in the Orient where, according to Janse,[1] it is sought by the Chinese, who use it principally in religious ceremonies, but also in medicine and the perfuming of India inks. The Chinese are said to pay as much as $1.25 an ounce for it, and since the native producers are unable to supply the demand, a synthetic borneol, which is not a pure substance but a mixture of borneol and isoborneol, has entered the markets of the East.

Cineol, or eucalyptol, is a very important and valuable article of commerce. Its virtue as a remedial agent has placed it in a high position among the important drugs used in the treatment of human ailments. The uses of cineol are entirely medicinal. It is used both internally and externally, and also as an inhalant. It is administered internally in the form of various pharmaceutical preparations for the treatment of colds, pneumonia, bronchitis, and other respiratory affections. As an inhalant it is used for asthma, diphtheria, and throat troubles in general. Together with other medicaments cineol is applied externally in the form of ointments or liniments. Furthermore, it has a wide application in the manufacture of dentifrices, mouth washes, and other preparations where an antiseptic action is desired. At the present time pure cineol, as prepared from eucalyptus oil, commands a price of $1 to $2 a pound.

[1] Janse, J. M. Le Dryobalanops Aromatica Gaertn. et le Camphre de Borneo. Annales du Jardin Botanique de Buitenzorg, supplement 3, pt. 2, 1910, pp. 947-961.

PURPOSE OF THE INVESTIGATION OF WILD AROMATIC PLANTS NATIVE TO THE UNITED STATES.

Since many valuable volatile oils and volatile-oil constituents have been discovered in plants growing wild in various parts of the world, it has been thought that an investigation of the wild aromatic plants of this country would reveal many, now practically useless and possibly classed as weeds, which might become of commercial value.

The economic value of these plants is determined not only by the proportion of oil which they contain, but by the constituents of the oil; hence careful analyses must be made in order to discover what these constituents may be. The present bulletin deals with the analyses of three heretofore unutilized plants, which may be grouped together, because the oils obtained from them are all of a camphoraceous character and because they contain several constituents in common. These, gathered from different sections of the United States from entirely different habitats and belonging to unrelated families, are as follows: Black sage (*Ramona stachyoides*) from California, wild sage (*Artemisia frigida*) from South Dakota, and swamp bay (*Persea pubescens*) from Florida.

SPECIAL INVESTIGATIONS.

BLACK SAGE.

BOTANICAL DESCRIPTION AND DISTRIBUTION.

Ramona stachyoides (Benth.) Briquet (synonyms—*Audibertia stachyoides* Benth., *Salvia mellifera* Greene), commonly known as black sage (figs. 1 and 2), is a shrubby aromatic perennial, occurring from middle to southern California on low hills from April to June. The shrub attains a height of 3 to 6 feet and possesses herbaceous leafy branches with oblong leaves, green and wrinkled above and ash colored and hairy below The flowers are white or lilac and in whorls or heads. The leaves have a strongly aromatic and decidedly camphoraceous odor, the woody branches being very brittle and also strongly aromatic.

DISTILLATION OF THE OIL.

A quantity of the fresh herb partly in bloom, including the flowering tops, branches, and leaves, was distilled by steam in the vicinity of Los Angeles, Cal., in April, 1908, and yielded 0.75 per cent of oil. The oil was nearly colorless and possessed a penetrating, camphoraceous, yet agreeable odor, with a bitter, camphorlike taste. At 24° C. the specific gravity was found to be 0.9144; specific rotation $A_D = +30.2°$; re-fraction at 24° C., 1.4682. The oil was soluble with clear solution in 1½ volumes of 70 per cent alcohol, becoming turbid with 3½ volumes or over.

SEPARATION OF STEAROPTENE.

Owing to the very strong camphoraceous odor of the oil, a separation of the stearoptene suggested itself. In order to separate a solid body which is held in solution by a volatile oil, the "freezing-out" method is usually employed. Accordingly 100 grams of the oil were subjected to a freezing mixture of ice and salt. A temperature of $-15°$ C. was attained, and flaky crystals formed throughout the oil. The crystals were separated by being thrown on a force filter and the remaining oil again subjected to the cold, when a second lot was obtained, which was likewise separated. A total of

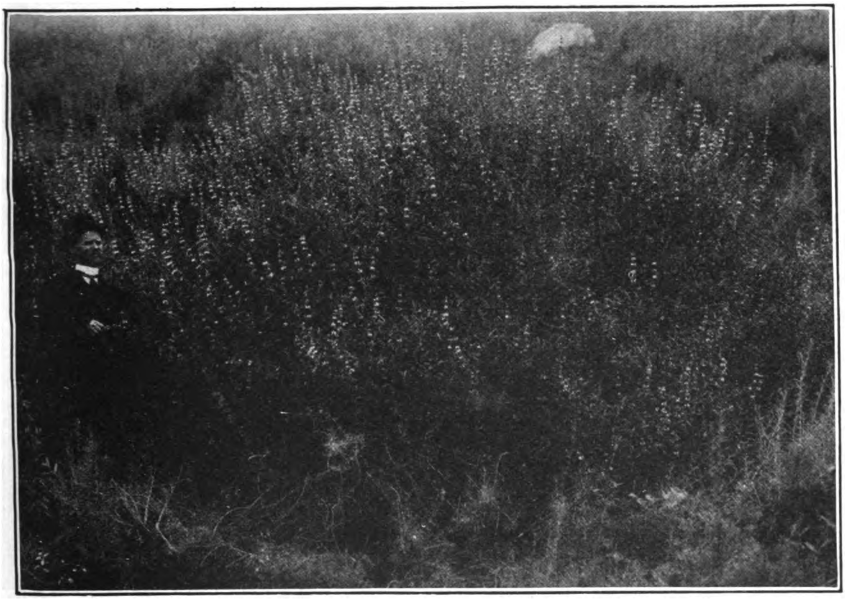

FIG. 1.—A plant of black sage (*Ramona stachyoides*) growing near Riverside, Cal.

11.3 grams of crystals was separated, corresponding to a yield of 11.3 per cent. These crystals were soft and flaky in nature and possessed the characteristic odor of camphor.

IDENTIFICATION OF CAMPHOR.

In order to identify the crystalline substance obtained from the oil, a small quantity was sublimed, and the usual tests of melting point, boiling point, and rotation were applied. For further recognition of the compound, an attempt was made to prepare an oxime. Accordingly the method of Auwers[1] was applied, which, briefly, is as

[1] Auwers, K. Zur Darstellung der Oxime. Berichte der Deutschen Chemischen Gesellschaft, vol. 22, 1889, pp. 604-607.

follows: To a solution of 10 parts of camphor in 10 to 20 times the amount of 90 per cent alcohol is added a solution of 7 to 10 parts of hydroxylamine hydrochlorid and 12 to 17 parts of a soda solution. If turbidity results, more alcohol is added and the mixture is heated on a water bath until a small portion of the solution remains clear upon the addition of water or until the resulting turbidity disappears,

FIG. 2.—Flowering top of a plant of black sage.

when a few drops of soda solution are added and no free camphor remains. The mixture is then diluted with water, filtered if necessary, and neutralized with dilute hydrochloric acid. The camphor oxime which separates is recrystallized from alcohol or ligroin. It melts at 118° to 119° C.

The above method applied to the sublimed crystals resulted in the formation of an oxime which melted at 120° to 124° C. Since

an oxime was obtained (indicating possible ketonic characters), application was made of another reaction for ketones, namely, the formation of semicarbazone. Tiemann's method[1] for the preparation of camphor semicarbazone was applied. The method is as follows: 1.5 grams of camphor dissolved in 2 cubic centimeters glacial acetic acid are treated with a solution of 1.2 grams of semicarbazid hydrochlorid and 1.5 grams of sodium acetate in 2 cubic centimeters of water. Water is added and the crystalline compound recrystallized from alcohol. The melting point of camphor semicarbazone is 236° to 238° C.

The sublimed crystals when treated in the above manner yielded a semicarbazone which melted at 232° C.

For a comparison of this substance with pure camphor, a tabulation was made of the more common physical properties and chemical tests.

TABLE I.—*Comparison of properties of crystals from oil of black sage and of pure camphor.*

Test.	Crystals from oil of black sage.	Crystals of pure camphor.
Melting point	174° to 175° C	175° C.
Boiling point	205° C.	204° C.
Rotation in 50 mm. tube	+3.33° (20 per cent solution in alcohol).	+3.51° (20 per cent solution in alcohol).
Oxime	M. p. 120° to 124° C	118° to 119° C.
Semicarbazone	M. p. 232° to 233° C	236° to 238° C.

The table shows very close similarities in the melting point, boiling point, and rotation of the crystals from the oil of black sage and of pure camphor. The melting points of the oximes and semicarbazones, though not corresponding so well, seemed to indicate that the crystals were in all probability camphor. To further confirm the assumption that the compound from the oil was camphor, an elementary analysis of the compound was made after being twice sublimed.

0.1273 gram of crystals gave 0.1199 gram H_2O, corresponding to 10.5 per cent hydrogen.

0.1273 gram of crystals gave 0.3228 gram CO_2, corresponding to 79.7 per cent carbon.

$$\frac{C_{10}H_{16}O}{\text{camphor}} \text{ requires} \begin{cases} 79 \text{ per cent carbon.} \\ 10.5 \text{ per cent hydrogen.} \end{cases}$$

0.1279 gram of crystals gave 0.1244 gram H_2O, corresponding to 10.8 per cent hydrogen.

0.1279 gram of crystals gave 0.3761 gram CO_2, corresponding to 79.9 per cent carbon dioxid.

[1] Michaelis, A., and Erdmann, G. Ueber die Thionylamine der Amidoazoverbindungen und der Naphtylendiamine. Berichte der Deutschen Chemischen Gesellschaft, vol. 28, 1895, pt. 2, pp. 2192–2204.

The combustion results seemed to indicate that the compound is identical with that of camphor, as the above tabulation also clearly shows.

CHEMICAL EXAMINATION OF THE OIL.

CHEMICAL CONSTANTS.

Preliminary to the detailed chemical examination of the oil the usual chemical constants were determined.

By neutralization of a weighed quantity of the oil with standard potassium hydroxid V. S., the acid number (the number of milligrams of potassium hydrate required to neutralize 1 gram of oil) was found to be 2.

The ester number (the number of milligrams of potassium hydroxid required to saponify the esters in the oil) was found to be 2.5, which, calculated as bornyl acetate, corresponds to 0.88 per cent.

The ester number after acetylization of the saponified oil with acetic anhydrid (and which represents the total amount of alcohols present) was 27.1, which, calculated as borneol, represents a total of 7.58 per cent of borneol in the oil, both free and in combination.

FREE ACIDS.

The original oil was slightly acid, as indicated by the acid number previously mentioned. The free acid was shaken out from a quantity of the oil with a 10 per cent solution of sodium carbonate. The shaking was repeated several times and the alkaline liquids united. The united alkaline liquids were shaken out with ether in order to remove any oil held in suspension. The sodium-carbonate solution was then evaporated to a small bulk on a water bath, acidified with sulphuric acid, and distilled with steam. No oily globules separated, showing absence of higher insoluble acids. The distillate, which was decidedly acid, was neutralized with sodium-carbonate solution and evaporated to a small volume. The liquid which now represented the sodium salts of the free acids present in the oil was precipitated fractionally with a dilute silver-nitrate solution. Four fractions resulted. Each fraction was dried to constant weight and burned.

Fraction 1. 0.1014 gram silver salt=0.0785 gram silver=76.3 per cent silver.
Fraction 2. 0.1000 gram silver salt=0.077 gram silver=77 per cent silver.
Fraction 3. 0.1116 gram silver salt=0.0859 gram silver=76.9 per cent silver.
Fraction 4. 0.1088 gram silver salt=0.077 gram silver=70.8 per cent silver.

Fraction 4 indicates the presence of formic acid, the silver salt of which requires, theoretically, 70.5 per cent of silver. Fractions 1, 2, and 3 indicate silver carbonate (which requires, theoretically, 78 per cent of silver) with a slight admixture of silver formate. The presence of silver carbonate was caused by a possible slight excess of sodium carbonate being added when the acid distillate was neutralized.

COMBINED ACIDS.

Saponification.—For the purpose of determining the acids held in combination in the oil in the form of esters, the oil was saponified with alcoholic potassium hydrate by heating on a water bath with a reflux condenser for one-half hour. Water was added to the mixture, and the oil separated in a layer. After removing the excess alcohol on a water bath, the alkaline solution was shaken out with ether to remove any adhering oil. The remaining solution was evaporated to a small volume, acidified with sulphuric acid, and distilled with steam.

The distillate from the above was extracted with ether and the ether evaporated spontaneously. Only a trace of an acid residue remained, which was neutralized with a solution of potassium hydroxid and precipitated in three fractions:

Fraction 1. 0.1012 gram silver salt=0.0893 gram silver=88 per cent silver.
Fraction 2. 0.0774 gram silver salt=0.0637 gram silver=82.3 per cent silver.
Fraction 3. 0.0758 gram silver salt=0.0502 gram silver=66.2 per cent silver.

The first two precipitates, when dried, consisted principally of silver oxid, which, theoretically, contains 89.2 per cent of silver. A slight excess of potassium hydroxid during neutralization was doubtless responsible. Fraction 3 would seem to point to the presence of acetic acid in the oil, silver acetate requiring 64.6 per cent of silver.

The aqueous acid portion remaining after the ether extraction was neutralized with sodium carbonate concentrated to small bulk and precipitated with silver nitrate in three fractions. Fraction 1 contained 76.2 per cent of silver; fraction 2, 77 per cent; and fraction 3, 74 per cent. Since silver formate contains 70.5 per cent of silver, a trace of formic acid is possibly present in the oil in combination.

The esters of the oil, as shown by the above results, are present in the oil principally as acetates, with a possible trace of formates.

FRACTIONATION OF THE OIL.

In order to ascertain the total percentage of camphor and to separate the remaining constituents as completely as possible, a quantity of the oil was fractionated into seven fractions, as follows:

Fraction 1, 160° C.; fraction 2, 160° to 170° C.; fraction 3, 170° to 178° C.; fraction 4, 178° to 182° C.; fraction 5, 182° to 186° C.; fraction 6, 186° to 190° C.; fraction 7, 190° to 195° C. These fractions (125 grams) were refractionated into 10 separate fractions, as shown in Table II, a determination of the physical properties of each fraction also being made.

TABLE II.—*Fractionation of the oil of black sage, showing the physical properties of the fractions.*

Fraction.	Temperature.	Distilled over.	Specific gravity at 26° C.	Rotation in 50 mm. tube.	Refraction N_D 28° C.	Remarks.
	Degrees C.	*Per cent.*		*Degrees.*		
1	Below 160	2.5	0.8070	+ 6.9	1.4570	Slight terebinthine odor.
2	160 to 170	6.8	.8768	+10.1	1.4613	Cineol-like odor.
3	170 to 174	7.8	.8865	+10.1	1.4640	Do.
4	174 to 178	12.1	.8920	+10	1.4648	Decidedly cineol-like odor.
5	178 to 182	14.8	.8996	+10.2	1.4652	Do.
6	182 to 186	8.6	.9077	+11.5	1.4659	Slight camphoraceous odor.
7	186 to 190	8	.9105	+11.1	1.4673	Strong camphoraceous odor.
8	190 to 195	8.1	.9130	+11.7	1.4683	Do.
9	195 to 200	7.7	.9170	+11.6	1.4710	Do.
10	200 to 208	11.6	.9220	+10.4	1.4710	Do.
Residue	208 and above	12	.9236	....	1.4854	Do.

IDENTIFICATION AND SEPARATION OF THE CONSTITUENTS.

Pinene.—The first fraction distilling below 160° C., and which possessed an odor of turpentine, was tested for pinene by means of the nitrochlorid reaction.[1] A deep blue coloration was obtained with slight turbidity, indicating a possible trace of pinene.

Cineol, or eucalyptol.—Tests were made in fractions 2, 3, 4, 5, and 6 for cineol, which was easily recognized by its odor. For a qualitative test the iodol reaction was used, crystals of cineol iodol which melted at 111° to 112° C. forming in each fraction. Fractions 3, 4, and 5, which smelled strongly of cineol and which doubtless contained the major portion of cineol in the oil, were assayed by means of the phosphoric acid method, as directed in the United States Pharmacopœia for 1900.[2] From these four fractions a total amount of 22.5 per cent of cineol was obtained, calculated from the original oil. This figure represents approximately the percentage of cineol in the oil, although it is low rather than high, since fractions 2 and 6 both showed the presence of cineol by qualitative tests, but the quantitative estimation in these fractions was impossible owing to the preponderance of other constituents in the fractions.

A test for terpinene in fraction 6, by means of the terpinene nitrosite reaction, produced a characteristic blue coloration, but the crystalline nitrosite would not separate.

Camphor.—A strong odor of camphor being distinguishable in fractions 7, 8, 9, 10, and in residue, a quantitative separation was made as completely as possible by means of the "freezing-out" method. Between 186° and 190° C. some crystals of camphor began to form in the inner tube of the condenser, and at 195° C. the condenser had to be kept jacketed with steam to prevent clogging, so rapidly did the camphor distill over. The fractions above 195° C. were practically

[1] Wallach, O. Zur Kenntniss der Terpene. Justus Liebig's Annalen der Chemie, vol. 245, 1888, p. 251.
[2] Pharmacopœia of the United States, 8th decennial revision, 1900, p. 313.

solid. The camphor which separated at ordinary temperature was filtered on a force filter, and the liquid portion of the fractions subjected to freezing successively until camphor no longer separated. It is apparent that the separation of the camphor from these small fractions by freezing out is rather inaccurate because of the losses in transferring and filtering. From the above fractions, however, a quantity of camphor was obtained corresponding to about 40 per cent of the original oil. This figure is low, for the separation on a larger scale working with much larger fractions would reduce to a considerable degree the loss of camphor which is unavoidable in such small fractions.

The fractions distilling between 195° and 208° C. yielded crystals when treated with bromin in a petroleum-ether solution of the oil. The crystals melted at 130° C. Thujone tribromid melts at 122° C. A trace of thujone is therefore probably present in the oil. It is very possible, in view of the fact that the acetylization of the oil disclosed some free alcohol, that the last fraction contained some borneol, which boils at 212° C.

SUMMARY.

The results of the experiments would seem to indicate that the oil of black sage is composed essentially of camphor (more than 40 per cent) and cineol (22.5 per cent), with a small quantity of an alcohol, probably borneol, both free and as an ester, and a small quantity of the ketone thujone, with traces of the terpenes pinene and terpinene. Free formic acid was found, and only traces of combined acetic and formic acids in the form of esters.

The constituents of possible economic importance in the oil are camphor and cineol, both of which possess considerable medicinal value, the former being used also very extensively in the arts. These constituents, possessing strong antiseptic virtues, no doubt impart antiseptic properties to the oil. Inasmuch as the yield of oil from the fresh herb approximates 1 per cent, if distilled during the full flowering stage, and furthermore, since the plant thrives on low sandy hills or wastes, it is very probable that the shrub could be grown profitably both for its oil and for the large amount of camphor and cineol capable of being isolated from it.

WILD SAGE.

BOTANICAL DESCRIPTION AND DISTRIBUTION.

Artemisia frigida Willd., commonly known as wild sage, mountain sage, pasture sagebrush, and wormwood sage (figs. 3 and 4), is a hardy perennial 6 to 20 inches high, with a woody base and white silky

leaves. The numerous yellow flowers, arranged in a racemelike head, possess a strongly camphoraceous odor. The leaves are also strongly aromatic. The plant abounds on dry sandy hilltops from the Dakotas west to Idaho, north into Canada, and as far south as Texas.

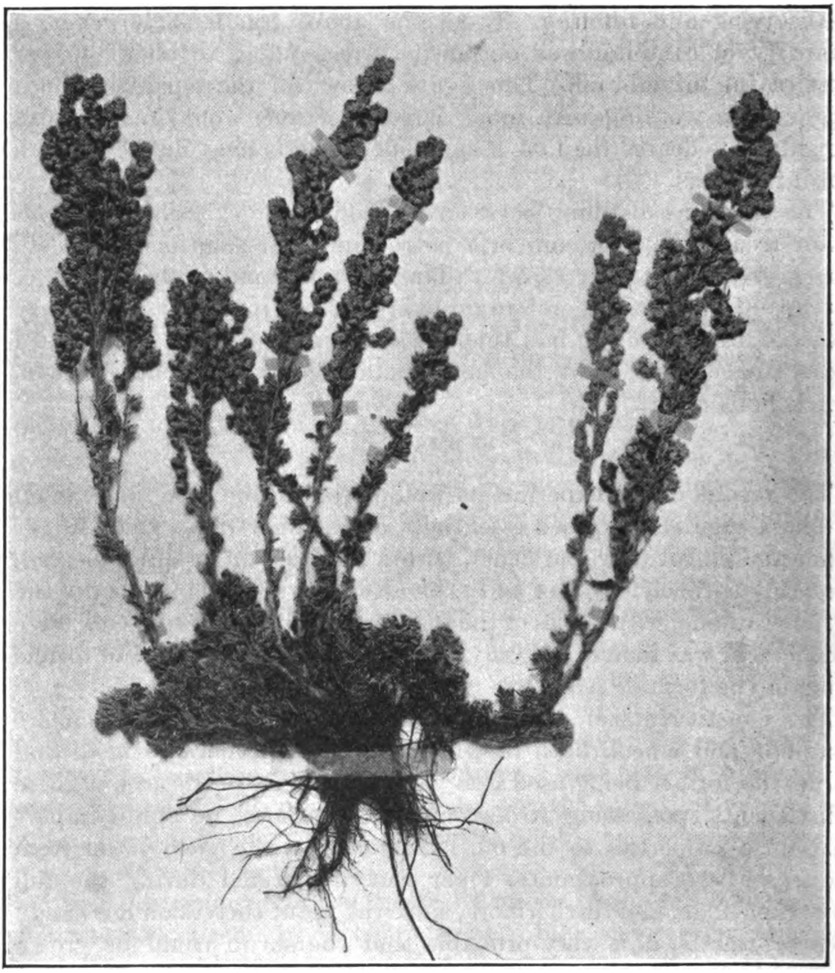

FIG. 3.—A plant of wild sage (*Artemisia frigida*).

DISTILLATION OF THE OIL.

The oil distilled from wild sage was briefly reported by the writer in 1905[1] and 1906.[2] The promising preliminary results encouraged a further investigation of this plant. During the summers of 1907 and 1908 larger quantities of this interesting wild plant were distilled

[1] Rabak, Frank. On Several New Artemisia Oils. Pharmaceutical Review, vol. 23, 1905, pp. 128–129.
[2] Ibid., vol. 24, 1906, pp. 324–325.

in South Dakota, a yield of 0.26 per cent of a very fragrant essential oil being obtained from plants which had passed their flowering stage. When the plant is distilled during its flowering stage the yield of oil is about 0.41 per cent.

The oil obtained by the distillation of the whole plant was beautiful pale green in color, with an agreeable fatty and camphoraceous odor and a slightly bitter camphorlike taste. The specific gravity of the oil at 24° was 0.940; specific rotation $A_D = -24.2°$; re-fraction N_D 24°, 1.4716. The oil was soluble in 1 volume of 80 per cent alcohol, becoming turbid in 2 volumes or over.

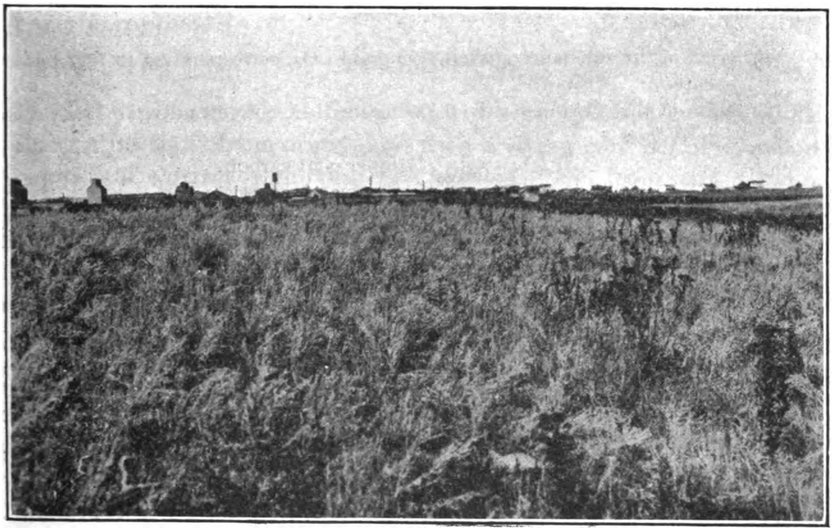

FIG. 4.—A field of wild sage near Webster, S. Dak.

SEPARATION OF STEAROPTENE.

During the distillation and filtration of the oil, small crystals were observed at the mouth of the distillation apparatus and also at the mouth of the funnel after standing over night. In order to separate this stearoptene (solid portion of the oil) from the elaoptene (liquid portion) 50 grams of the oil were subjected to a freezing mixture of ice and salt for several hours. As a result crystals separated in the form of white flakes. The crystals were thrown into a force filter and weighed, a total of 3 per cent resulting.

IDENTIFICATION OF CRYSTALLINE COMPOUND.

After recrystallization of the above crystals from alcohol the properties of the crystals compared very favorably with levo borneol, as shown in Table III.

TABLE III.—*Comparison of properties of crystals from oil of wild sage and of pure borneol.*

Test.	Crystals from oil of wild sage.	Crystals of pure borneol.
Color	White	White.
Odor	Camphorlike	Camphorlike.
Taste	Bitter, camphorlike	Bitter, camphorlike.
Boiling point	210° to 215° C.	212° C.
Melting point	203° C.	203° to 204° C.
Specific rotation	−32°.	−37°.

To further confirm the above results, which seemed to indicate that the compound was identical with levo borneol, an elementary analysis was made.

0.1237 gram of the substance gave 0.3499 gram CO_2, corresponding to 77.2 per cent carbon.

0.1237 gram of the substance gave 0.1252 gram H_2O, corresponding to 11.4 per cent hydrogen.

$$\frac{C_{10}H_{18}O}{\text{borneol}} \text{ requires} \begin{cases} 77.8 \text{ per cent carbon.} \\ 11.7 \text{ per cent hydrogen.} \end{cases}$$

The elementary composition substantiates the assumption that the crystals are identical with levo borneol.

CHEMICAL EXAMINATION OF THE OIL.

CHEMICAL CONSTANTS.

The usual chemical constants were determined, namely, the acid number, ester number, saponification number, and acetylization number.

The acid number, denoting the amount of free acids contained in the oil and expressed in milligrams of potassium hydroxid, was determined by simple neutralization of the oil with standard potassium hydrate volumetric solution.

The ester number, denoting the amount of esters (combination of alcohols and acids) in the oil and expressed in milligrams of potassium hydroxid, was determined by saponification of the ester compounds with alcoholic potassium hydrate.

The acetylization number, or the ester number determined after acetylization of the oil with acetic anhydrid, signifies the total amount of alcohol or alcohols in the oil.

The constants of the oil were determined with the following results:

Acid number, 2.5, calculated as acetic acid, indicates 0.26 per cent acetic acid.

Ester number, 25, calculated as bornyl acetate, indicates 8.7 per cent bornyl acetate, which is equivalent to 6.8 per cent of free borneol.

Saponification number, 27.5.

Acetylization number, 139, corresponds to 42.67 per cent of total borneol in the oil, or, deducting the 6.8 per cent of free borneol as the ester, to 38 per cent of free borneol.

Assuming that the stearoptene obtained was borneol, a determination of the constants of the stearopteneless oil was made. The acid number remained practically the same, being 2.3; the ester number differed only very slightly, being 24.7; but the acetylization value obtained was only 132, which corresponded to but 40 per cent of total borneol. This is in strict conformity with the assumption, which seemed to be sufficiently proved, that the stearoptene separated from the oil by freezing was borneol. The stearopteneless oil was nearly 3 per cent poorer in borneol than the original oil, as shown above. It is to be remembered that 3 per cent of crystalline borneol was removed by freezing the original oil, hence the lowering of the borneol content of the stearopteneless oil.

FREE ACIDS.

The determination of the free acids was accomplished by repeatedly shaking a portion of the original oil with a 10 per cent sodium carbonate solution. After removing the adhering oil from the alkaline liquid by shaking with ether, the solution was acidified and distilled with a current of steam. A few oily globules floated on the surface of the liquid. These were extracted with ether and the ether evaporated. A small amount of oily residue remained, which was distinctly acid. The oily residue was exactly neutralized with sodium hydrate and precipitated with silver nitrate solution in three fractions:

Fraction 1. 0.0377 gram silver salt gave 0.0162 gram silver=42.9 per cent silver.
Fraction 2. 0.0206 gram silver salt gave 0.0091 gram silver=44.1 per cent silver.
Fraction 3. 0.0663 gram silver salt gave 0.3000 gram silver=45.2 per cent silver.

The three fractions appear to be a mixture of caprylic and œnanthylic acids. Silver caprylate requires 42.9 per cent silver; silver œnanthylate requires 45.5 per cent silver.

A small amount of the insoluble free acids was therefore caprylic acid (octoic acid), the major portion being œnanthylic acid (heptoic acid).

The distillate from which the oily acids were extracted by ether was still slightly acid and was accordingly neutralized with sodium carbonate and precipitated with silver nitrate, two fractions being obtained. The first corresponded to silver carbonate, due to a slight excess of sodium carbonate; the second, only trifling in quantity, indicated the presence of only a trace of formic acid in the free condition.

Œnanthylic, or heptoic, acid seems to be the predominating free acid in the oil, with slight traces of formic and caprylic, or octoic, acids.

COMBINED ACIDS.

The esters in the oil, being combinations of alcohols and acids, serve as a basis for the identification of the acids in combination. In order to accomplish a separation of the combined acids a small quantity of the oil was saponified with alcoholic potassium hydroxid by heating on a water bath for half an hour. After dilution of the mixture with water and separation of the oil the alkaline liquid, which contained a small amount of the oil held in suspension, was shaken out with ether. The liquid was then acidified with sulphuric acid and distilled with steam. The oily globules which separated on the distillate were extracted with ether and the solvent evaporated. A small amount of an oily liquid with very offensive odor remained. This mixture of oily acids was neutralized with sodium hydrate and precipitated with a dilute solution of silver nitrate. Two fractions resulted:

Fraction 1. 0.0430 gram silver salt gave 0.0160 gram silver=37.2 per cent silver.
Fraction 2. 0.0440 gram silver salt gave 0.0197 gram silver=44.7 per cent silver.

From the results obtained it is evident that the fractions consist of the silver salt of undecylic acid, which requires theoretically 36.8 per cent of silver, and silver salt of heptoic (œnanthylic) acid, which requires 45.5 per cent of silver.

The aqueous distillate from the above, after being made neutral with sodium carbonate, was evaporated to small volume and precipitated in three fractions with silver nitrate:

Fraction 1. 0.243 gram silver salt gave 0.1837 gram silver=75 per cent silver.
Fraction 2. 0.3255 gram silver salt gave 0.2370 gram silver=72.9 per cent silver.
Fraction 3. 0.3492 gram silver salt gave 0.1840 gram silver=52.9 per cent silver.

The greater portion of the soluble combined acids consisted of valerianic acid, the silver salt requiring 51.6 per cent of silver. A trace of formic acid was also indicated in combination as an ester in fraction 2, above.

The chief acids in combination as esters in the oil appear to be œnanthylic (heptoic) and valerianic, the former being preponderant. Formic and undecylic acids occur only as traces. All of the above are no doubt combined in the oil as esters of borneol.

FRACTIONATION OF THE VOLATILE OIL.

One hundred grams of the original oil were subjected to fractionation and separated into six fractions of 5 degrees each, beginning with 175° C. These fractions together with the residue were again fractionated in order to insure a better separation of the constituents.

TABLE IV.—*Fractionation of oil of wild sage, showing the physical and chemical properties of the fractions.*

Fraction.	Temperature.	Distilled.	Specific gravity at 24° C.	Rotation in 50 mm. tube.	Ester number.	Remarks.
	Degrees C.	*Per cent.*		*Degrees.*		
1	Below 175[1]	13.6	0.9084	− 9.5	2.6	Eucalyptuslike (cineol) odor.
2	175 to 180	14.0	.9196	− 8.1	6.7	Do.
3	180 to 185	6.0	.9269	− 7.6	8.9	Do.
4	185 to 190	4.5	.9313	− 6.4	12.0	Slightly camphoraceous odor.
5	190 to 195	10.0	.9401	− 8.6	25.8	Camphoraceous odor.
6	195 to 205	9.5	.9478	− 9.7	34.8	Decidedly camphoraceous; free borneol crystallized in condenser.
7	205 to 215	9.0	.9562	−10.6	56.4	Fraction almost solid (borneol).
8	215 to 230	9.5	.9600	−10.8	75.2	Fraction partially solidified.
9	230 to 245	3.5	.9570	− 5.8	70.7	Few crystals separated.
10	245 and above	9.0	.9830	....	47.0	Dark, sirupy, camphoraceous.

[1] This fraction distilled largely between 170° and 175° C.

IDENTIFICATION AND SEPARATION OF THE CONSTITUENTS.

Cineol.—Fraction 1, 175°C, possessed a strong eucalyptuslike odor and was tested for cineol by means of iodol. The tetraiodopyrol (iodol) addition product of cineol formed into well-defined, nearly colorless crystals, melting at 110° to 113° C. This crystalline addition product of iodol formed in the first four fractions; in fraction 5, however, only a trace of crystals appeared.

The presence of cineol having been proved, a quantitative estimation of the compound was made in fractions 1, 2, 3, and 4. Fraction 5, which contained only a very small quantity of cineol, did not admit of estimation by the phosphoric-acid method, which is reliable only when large percentages of cineol are present.

The fractions yielded the following percentages of cineol: 1, 40 per cent; 2, 70 per cent; 3 and 4, 43.7 per cent. Calculating from the original oil as a basis, the above results correspond to 19.7 per cent of cineol in the original oil.

Fenchone.—Fraction 5, boiling from 190° to 195° C., was a heavy liquid with a strong camphorlike odor. Pure levo fenchone[1] from thuja oil is an oily liquid with a strong camphoraceous odor; boiling at 192° to 194° C.; specific gravity at 19° C., 0.946; $(A_D) - 66.9°$.

An oxime was prepared from the fraction by reaction with hydroxylamine hydrochlorid according to the method of Wallach,[2] which is as follows: To 5 grams of fenchone dissolved in 80 cubic centimeters of absolute alcohol is added a solution of 11 grams of hydroxylamine hydrochlorid in 11 grams of hot water. Six grams of powdered potash are added. The oxime separates in the form of crystals, upon standing for some time. Recrystallized from alcohol it melts at 164° to 165° C.

[1] Wallach, O. Zur Kenntniss der Terpene und der ätherischen Oele. Justus Liebig's Annalen der Chemie, vol. 272, 1892, p. 102.

Ibid., p. 104.

The oxime formed from the fraction by the above method, after recrystallization from ethyl acetate, melted at 170° C.

Provided that fraction 190° to 195° C. consists chiefly of fenchone the oil should contain 8 to 10 per cent of this compound.

Borneol.—The total amount of borneol contained in the oil was determined by the saponification of a small quantity of the original oil and subsequently fractionating the saponified oil. Twenty-five grams of the saponified oil were carefully fractionated and then refrigerated, 7.5 grams of borneol separating out. This corresponds to a total of 30 per cent borneol. After the separation of the borneol the oil was again fractionated, and the portion above 195° C. yielded, when frozen, an additional 2 grams of borneol, making a total of 9.5 grams, or 38 per cent, of total borneol separated from the oil. The theoretical quantity of borneol in the oil, as shown by the acetylization value, is about 43 per cent, the lower percentage which was actually obtained being caused by incomplete separation due to the smallness of the amount saponified.

Esters of borneol.—A careful examination of Table IV shows that the esters of borneol, possibly chiefly bornyl heptoate and valerianate, are found in the fractions boiling above 190° C., principally in the highest boiling fractions; a perfect separation of these esters was not feasible because of the existence of the esters as mixtures of several acids. The ester numbers of the fractions, however, show the distribution of the esters at the different temperatures.

SUMMARY.

Briefly summarizing the results of the analyses, the oil of wild sage may be said to be composed: (1) Of total borneol camphor, 43 per cent, of which about 6.8 per cent exists as bornyl heptoate (calculating the esters of the oil as heptoic acid salts of borneol), leaving 35.8 per cent of free borneol camphor present in the oil; (2) of cineol (eucalyptol), 18 to 20 per cent; (3) of fenchone, 8 to 10 per cent; (4) of free acids, chiefly œnanthylic, or heptoic, acid, 0.58 per cent, with traces of formic and caprylic acids; (5) of combined acids in form of esters, chiefly, œnanthylic acid, with smaller quantities of valerianic, undecylic, and formic acids. It is very probable that a small amount of terpenes were also present in the portion distilled below 175° C., which, however, were not identified.

As will be noted from the above, the chief constituents of the oil of wild sage are borneol camphor and cineol, each of which possesses valuable antiseptic qualities. Since there is a high percentage of these constituents, the oil from this wild plant should prove of value for medicinal purposes. Another important use of the oil is suggested by the high content of borneol, a constituent which finds application

in celluloid manufacture, and which is readily separated from this oil. Lastly, combining the agreeable aromatic quality with its antiseptic qualities, the oil should prove important as an ingredient of medicinal soaps or as a scenting substance.

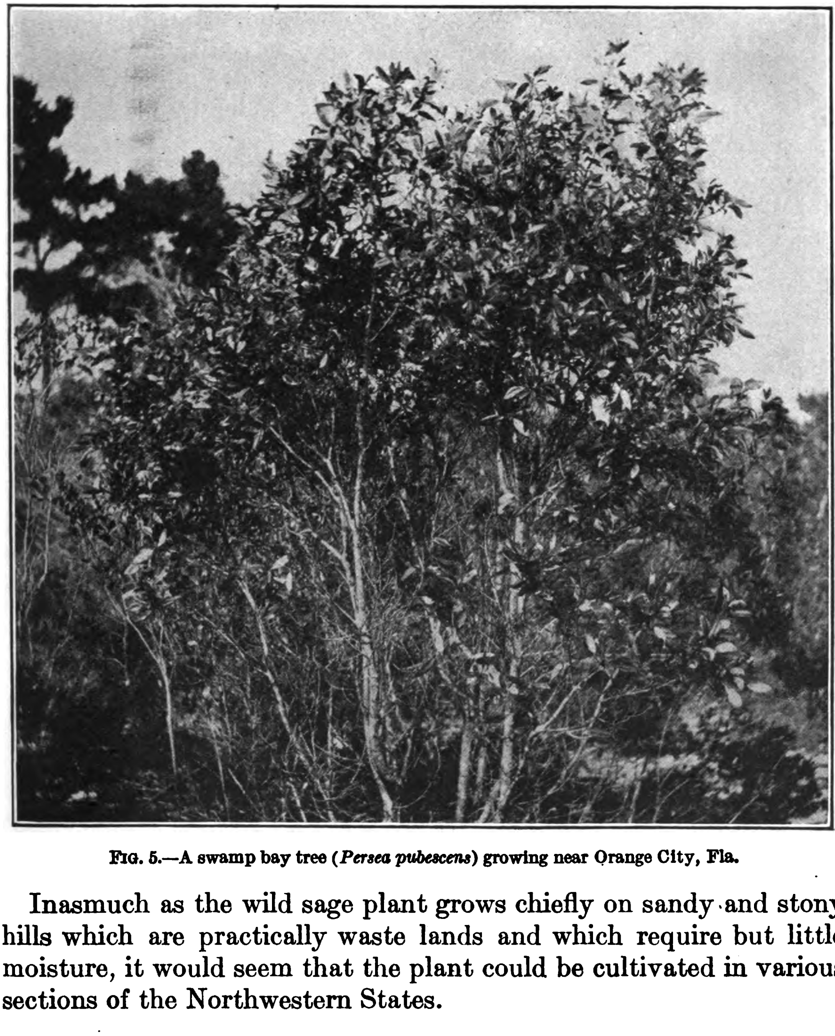

FIG. 5.—A swamp bay tree (*Persea pubescens*) growing near Orange City, Fla.

Inasmuch as the wild sage plant grows chiefly on sandy and stony hills which are practically waste lands and which require but little moisture, it would seem that the plant could be cultivated in various sections of the Northwestern States.

SWAMP BAY.

BOTANICAL DESCRIPTION AND DISTRIBUTION.

Persea pubescens (Pursh.) Sarg., commonly known as swamp red bay or swamp bay (figs. 5 and 6), is an aromatic evergreen tree attaining a height of 30 feet or more, but usually occurring as a shrub. The leaves and twigs of the tree possess a pleasant camphoraceous

odor. The swamp bay occurs abundantly in swamps and hammocks from North Carolina to Florida and Texas. The tree is a member of the family Lauraceæ, to which the camphor tree belongs.

DISTILLATION OF THE OIL.

Because of the strong camphoraceous odor and its close relationship to the camphor tree, the extraction and possible utilization of the oil from this wild aromatic plant suggested itself. Accordingly, during the summer of 1910, with the assistance of Mr. S. C. Hood, in charge

FIG. 6.—A small branch of swamp bay.

of the station at Orange City, Fla., a small quantity of the leaves and twigs of this plant was distilled and a yield of about 0.2 per cent of oil was obtained. But with proper conditions and precautions the yield could no doubt be very materially increased, depending largely upon the time at which the distillation is made, and also upon the proportion of twigs and branches included. The above distillation was made late in the summer, long after the blossoming period, the stage at which a plant is usually most productive in volatile oils, and the material also contained many branches and much woody matter.

The oil obtained was pale yellowish brown in color, with a strongly aromatic and camphoraceous odor, and a persistent bitter, slightly pungent, and camphorlike taste. The specific gravity at 25° C. was 0.9272; specific rotation, $A_D = +22.4°$; refraction, N_D $25° = 1.4695$. The oil was soluble in one-third its volume of 80 per cent alcohol, becoming faintly turbid upon the addition of five volumes or more of alcohol.

CHEMICAL EXAMINATION OF THE OIL.

CHEMICAL CONSTANTS.

A preliminary examination of the oil disclosed considerable free acidity, the acid number being 2.8, while the ester content was rather low, the ester number being 14.5. The low ester number would seem to indicate a low percentage of alcoholic compounds in combination with acids, and would correspond to 4.9 per cent of esters calculated as the acetate of borneol. After acetylization of the oil with acetic anhydrid the saponification number was found to be 64, which corresponds to 14.6 per cent of free alcohol, calculated as borneol.

In order to identify conclusively the constituents of the oil and the forms in which they occur, and to separate quantitatively the predominant constituents, the oil was subjected to a more careful and detailed analysis.

FREE ACIDS.

The free acidity of the oil as indicated by the preliminary tests was removed by shaking with 10 per cent aqueous sodium carbonate solution in several portions. The aqueous alkaline extracts, after being deprived of any adhering oil by extraction with ether, were concentrated, acidified, and distilled with a current of steam. The acids which were obtained separated principally as oily globules on the aqueous distillate, which was only faintly acid.

The free insoluble acids which were separated from the aqueous distillate by extraction with ether and evaporation of the solvent were neutralized with a solution of potassium hydroxid and then precipitated in fractions with a solution of silver nitrate.

Fraction 1. 0.0227 gram silver salt gave 0.0130 gram silver=57.2 per cent silver.
Fraction 2. 0.0213 gram silver salt gave 0.0119 gram silver=55.8 per cent silver.

It appears from the above results that the only acid existing in the free state in the oil is butyric acid, since silver butyrate gives theoretically 55.3 per cent of silver, fraction 1 being slightly contaminated, due possibly to a slight excess of potassium hydrate which was added when the acids were neutralized and which would appear in the first precipitate.

From the remaining faintly acid distillate, after neutralization with barium carbonate and concentrating, only a trace of precipitate,

insufficient for silver determination, resulted upon the addition of silver nitrate solution. The butyric acid detected in the free insoluble acids was evidently extracted by the ether, in which it is very soluble.

COMBINED ACIDS.

As stated previously, the oil was found to contain a small percentage of esters, or organic acids in combination with higher alcohols. In order to identify these acids, which are in combination in the form of esters, a quantity of the oil, after removing the free acids, was saponified by heating on a water bath for half an hour with a slight excess of alcoholic potassium hydroxid. The mixture, after saponification, was diluted with water and the unsaponified oil separated. The alkaline liquid, which now contained the combined acids as their potassium salts, after being freed from adhering particles of oil by shaking with ether, was acidified with sulphuric acid and distilled with steam. The insoluble oily acids which formed on the distillate were separated by shaking the distillate lightly with ether and evaporating the ether.

SOLUBLE COMBINED ACIDS.

The aqueous portion of the distillate which contained the soluble combined acids of the oil was neutralized with barium carbonate, concentrated and precipitated with silver nitrate solution. Only a small precipitate resulted. This precipitate was found to contain 55.9 per cent of silver, which corresponds to silver butyrate. Hence the acid in the distillate was butyric acid.

INSOLUBLE COMBINED ACIDS.

As heretofore stated, the insoluble oily acids obtained by extraction with ether were carefully neutralized with potassium hydroxid solution and precipitated fractionally with silver nitrate. Two precipitates were obtained which were thoroughly washed and dried. The first and largest precipitate assayed 51.2 per cent silver, the second assaying 45.1 per cent silver. This would indicate that the insoluble acids were valerianic acid (silver valerianate requiring 51.6 per cent silver), and heptoic acid (silver heptoate requiring 45.5 per cent silver), the valerianic acid predominating.

The results show that the esters of this oil exist as the salts of butyric, valerianic, and heptoic acids, valerianic acid esters, however, predominating.

FRACTIONATION OF THE OIL AND SEPARATION OF THE STEAROPTENE.

For the purpose of accomplishing a separation of the constituents, 50 grams of the oil, after saponification, were dried and subjected to fractional distillation in a three-bulb Ladenburg flask. The results are given in Table V.

TABLE V.—*Fractionation of saponified oil of swamp bay and description of fractions.*

Fraction.	Temperature.	Distilled.	Remarks.
	Degrees C.	*Per cent.*	
1	Below 170	1.1	Penetrating odor; largest portion of the fraction distilled over below 80° C.; temperature rose rapidly to 170° C.
2	170 to 182	8.8	Camphoraceous cineol-like odor; largest portion distilled 175° to 180°.
3	182 to 185	9.2	Strong cineol-like odor; temperature rose uniformly.
4	185 to 190	13.5	Cineol-like camphoraceous odor; temperature rose uniformly.
5	190 to 195	13.0	Strong camphoraceous odor; temperature rose uniformly.
6	195 to 200	5.8	Strong camphorlike odor; crystals appeared in condenser;[1] largest portion distilled between 198° to 200° C.
7	200 to 205	12.5	Strong camphorlike odor; fraction semisolid upon cooling; temperature rose uniformly.
8	205 to 215	14.0	Strong camphorlike odor; fraction almost solid upon cooling; distilled largely between 205° to 210° C.
9	215 to 225	12.5	Strong camphoraceous odor; fraction semisolid; temperature rose uniformly.
10	225 and above.	9.0	Heavy yellow oil with camphoraceous odor.

[1] To prevent clogging of the condenser with crystals, the jacket of the condenser was deprived of the cold water, and steam passed through, the melted crystals passing over. The crystals immediately reappeared in the fractions upon cooling.

Beginning with fraction 6 each successive fraction was refrigerated in a freezing mixture of ice and salt and the crystals separated by centrifuging in a platinum Gooch crucible. A total of 13.7 per cent of crystals was obtained.

In order to obtain a further separation of crystals the portions of the oil beginning with fraction 5 were fractionated into the following fractions: 190° to 195° C.; 195° to 200° C.; 200° 205° C.; 205° to 215° C.; 215° to 233° C.; 233° to 260° C. A total of 4 per cent of crystals was obtained by refrigeration and centrifugation of those fractions in which crystals appeared. The portion between 190° and 215° C., and also fraction 4 of the original, were further fractionated into four parts: 185° to 190° C.; 190° to 195° C.; 195° to 205° C.; 205° to 215° C., an additional yield of 3.3 per cent of crystals being obtained.

By the above method of successive fractionation and refrigeration a total of 21 per cent of crystals was obtained from the oil. This represents only approximately the total percentage of stearoptene in the oil. The separation was not at all quantitative, as a considerable proportion was lost in the manipulations incident to the separation. Since the quantity of oil at hand was so meager the fractions were reduced to such small quantities that further separation of crystals was impossible, and as unavoidable losses were encountered in transferring to and from the centrifuge the final percentages were materially affected and the true amount of stearoptene may be assumed to be considerably more than is shown above.

After the fractionation and refractionation of the oil and the separation of the stearoptene portion, the remaining elaoptene portion grouped itself into fractions, whose physical properties were determined and qualitative tests for their constituents applied, as shown in Table VI.

TABLE VI.—*Refractionation of the oil of swamp bay, showing the physical properties of the fractions.*

Fraction.	Temperature.	Specific gravity at 25° C.	Rotation in 50-mm. tube.	Refraction N_D 25°.	Tests applied.
	Degrees C.		*Degrees.*		
1	Below 170.....	Insufficient.	Insufficient.	1.4648	When shaken with water the aqueous solution strongly reduced magenta solution to violet color; also produced silver mirror with ammoniacal silver nitrate.
2	170 to 182.....	0.9011	+22.5	1.4630	Iodol (tetraiodopyrol) dissolved in oil by gentle warming yielded yellow crystals melting at 115° C.; cineol iodol melts at 112° C.
3	182 to 185.....	.9012	+21.5	1.4628	Treated with iodol and the yellow crystals recrystallized from benzol melted sharply at 112°.
4	185 to 190.....	.9075	+ 23	1.4628	Cineol-iodol crystals melted at 113° C.
5	190 to 205.....	.9228	+ 31	1.4653	Do.
6	205 to 215.....	.9351	....	1.4706	Negative test with iodol.
7	215 to 233.....	.9358	....	1.4765	Do.
8	233 to 260.....	.9360	....	1.4830	Oxidized with 3 per cent potassium permanganate in cold yielded camphor crystals.

IDENTIFICATION OF THE CONSTITUENTS OF THE OIL.

Camphor.—The compound obtained from the oil by refrigeration was a soft, white, granular, crystalline mass, and possessed a distinct camphorlike odor and slightly bitter camphoraceous taste. The crystals sublimed readily and melted at 174° to 176° C. The boiling point of the compound was 205° C., and the rotation in a 50 mm. tube of 20 per cent solution in alcohol was found to be +3.8°, 20 per cent solution of commercial camphor in alcohol rotating +3.5°. It was readily soluble in alcohol and the other organic solvents.

To further identify the crystals with ordinary camphor two compounds were prepared, the semicarbazone and the oxime, with which camphor forms definite chemical compounds. The semicarbazone was prepared according to the method of Tiemann. (See p. 17.) The crystals obtained after recrystallization from alcohol melted at 237° to 239° C., pure camphor semicarbazone melting at 236° to 238°. For the preparation of the oxime Auwer's method was applied. (See p. 16.) Recrystallized from ether the oxime melted at 117° to 118° C., whereas pure camphor oxime melts at 118° to 119° C.

Since the physical and chemical properties of this substance correspond almost identically with those of camphor, it may be safely stated that the crystals are those of commercial dextro camphor.

Aldehyde constituent.—From the pungent and penetrating odor and the strong reducing properties of the first fraction, which, as shown in Table V, distilled largely below 80° C., there would seem to be the possible presence of a trace of formaldehyde.

Cineol, or eucalyptol.—Qualitative tests as indicated in Table V show the presence of cineol in fractions from 170° to 205° C., the characteristic crystalline cineol addition product of iodol corresponding in melting point to the pure cineol iodol. Cineol was further

identified in these fractions by the preparation of cineol hydrobromid prepared by passing dry hydrobromic acid gas into a well-cooled solution of the oil in petroleum ether. A crystalline hydrobromid was obtained from each fraction which gave the iodol reaction. The hydrobromids prepared melted between 55° to 57° C., while pure cineol hydrobromid is reported as melting at 56° to 57° C.

Since the presence of cineol in the several fractions of the oil was proved, a quantitative estimation was deemed desirable. Because of the smallness of the individual fractions the hydrobromic acid method was adopted in this estimation, it being the most accurate when cineol is present in only small quantities. The phosphoric acid method is best adapted to oils which are very rich in the compound. The hydrobromic acid method has been used in the assay of eucalyptus oils,[1] and consists essentially in conducting dry hydrobromic acid gas into a solution of the oil in about twice its volume of petroleum ether, the solution being well cooled by a freezing mixture, separating the crystals on a force filter, washing and decomposing with water, and measuring the cineol formed. A slight deviation was made from the directions on account of the smallness of the fractions and consequently the small amount of hydrobromid obtained, which when decomposed with water would introduce an error. After the hydrobromid of cineol was obtained in each case and washed it was weighed and the percentage of cineol was calculated from the weight of the crystals from a given quantity of each fraction. In this manner by assaying the four fractions which gave qualitative tests there was found to be a total of 19.8 per cent of cineol in the oil.

Borneol.—By oxidation of fraction 233° to 260° C. with a 3 per cent solution of potassium permanganate, slightly warming and allowing it to stand for 12 hours, then shaking out the mixture with ether and allowing the ether to evaporate, a mass of crystals remained which proved to be camphor. It is possible that borneol was present in this fraction, as borneol is readily oxidized to camphor with ordinary oxidizing agents. Since the preliminary chemical examination of the oil indicated a small percentage of esters and of free alcohol, the alcohol was probably borneol.

SUMMARY.

From the results obtained in the chemical examination it appears that the oil of swamp bay contains over 21 per cent of camphor, 19.8 per cent cineol, and borneol, the latter possibly occurring to a small extent as esters and as the free alcohol. No terpenes were identified. Since only a very small portion of the oil distills over below 175° C.,

[1] Gildemeister, Eduard, and Hoffmann, Friedrich. Translated by Edward Kremers. The Volatile Oils, p. 528.

it would seem that the oil is not terpenic in character, as most members of the terpene group of hydrocarbons boil below 175° C.

Besides the constituents mentioned, the oil contains butyric acid in free condition to a slight extent; butyric, valerianic, and heptoic acids combined in the oil as esters, valerianic acid predominating, and a slight trace of an aldehyde, possibly formaldehyde.

This oil possessing, as has been proved, considerable quantities of such constituents as camphor, cineol, and borneol, all of which are valuable therapeutic agents, may be of economic importance from the standpoint of the perfumer or the medical practitioner. Doubtless if the distillation of the plant were carried on, attention being paid to the stage of growth at which it is distilled and the distillation restricted to the leaves and small twigs, the yield of oil and possibly the yield of the three important constituents mentioned could be considerably augmented.

CONCLUSIONS.

The plants described in the foregoing pages and the volatile oils distilled from them represent but a small part of our wild aromatic flora, yet these plants gathered from their wild haunts have been made to yield products which give promise of no little economic importance. It is the object of this work simply to call attention to the products capable of being obtained from our native plants and to emphasize their possible application in the trades and arts. The actual growth and cultivation of such as prove to be of economic value should follow.

The lands on which the rankest growth of wild plants occurs are usually of little value for the production of agricultural crops, and doubtless large areas of this character exist in all sections of the United States, which lands might be utilized for the growth of certain aromatic plants now largely classed as weeds yet which may be made to yield products of value.

That there is a field for investigation in this direction is shown in the preceding pages in which three plants representing specimens picked up at random have been shown to yield oils containing large quantities of such important compounds as camphor, borneol, and cineol. Inasmuch as camphor is consumed in enormous quantities in the United States, the supply at present coming wholly from foreign countries, the presence of such large quantities of this substance in the volatile oils of black sage and swamp bay should not be overlooked. The cultivation of these plants should not be impracticable. Since black sage if distilled at its flowering stage could be made to yield approximately 1 per cent of oil from the green plant and the oil in turn be made to yield from 40 to 50 per cent of camphor, its growth and cultivation should be profitable. Furthermore, as the plant is a perennial, a crop of foliage could be produced each year, and the

luxuriant growth of the plant, coupled with the exceptionally high yield of oil would produce a large amount of oil and camphor per unit of area. After the separation of the camphor from the oil the camphor-free oil remaining would still possess value because of its high content of cineol.

The swamp bay, which yields oil and camphor, though in somewhat smaller quantities, should also receive attention along similar lines.

The wild sage is an example among the wild plants of the United States in which borneol is found in quantity. As a natural source for this compound the plant is far more promising than the two plants native to Borneo and the Malay Archipelago, which yield most of the borneol of commerce, supplying a large proportion to the Chinese, among whom there is a brisk demand. The abundance of wild sage found in this country, the ease with which it might be cultivated, and the large percentage of borneol and cineol capable of separation from the oil make it a most excellent source from which to obtain these substances. The oil also possesses virtues as a scenting agent because of the high percentage of the esters of borneol, which are excellent perfuming materials. As a source for the production of bornyl acetate which is extensively used by perfumers for its pine-needle odor, this oil should prove of value.

Since the oil from each of these plants shows important chemical constituents which may be commercially applied in many ways, their cultivation for these products is worthy of consideration.

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